Habit and physical activity

HABIT *and* PHYSICAL ACTIVITY

Moderation and mediation studies in older adults

ROB VAN BREE

HABIT AND PHYSICAL ACTIVITY

Moderation and mediation studies in older adults

Rob van Bree

Layout and cover design:	Design Your Thesis	|	www.designyourthesis.com
Printing:	Ridderprint BV	|	www.ridderprint.nl
ISBN:	978-94-6299-935-0		

The studies in this thesis were funded by the Netherlands Organization for Health Research and Development (Chapter 2-5: ZonMW, 6100.0003; Chapter 4-5: ZonMW, 200110006).

HABIT AND PHYSICAL ACTIVITY

Moderation and mediation studies in older adults

P R O E F S C H R I F T

ter verkrijging van de graad van doctor
aan de Open Universiteit
op gezag van de rector magnificus
prof. mr. A. Oskamp
ten overstaan van een door het
College voor promoties ingestelde commissie
in het openbaar te verdedigen

op vrijdag 29 juni 2018 te Heerlen
om 13.30 uur precies

door
Rob Johannes Henricus van Bree
geboren op 9 november 1977 te Helmond

Promotores
Prof. dr. L. Lechner, Open Universiteit
Prof. dr. C.A.W. Bolman, Open Universiteit

Co-promotor
Dr. A.N. Mudde, Open Universiteit

Leden beoordelingscommissie
Prof. dr. H. Aarts, Universiteit Utrecht
Prof. dr. G.J. Kok, Universiteit Maastricht
Prof. dr. S.P.J. Kremers, Universiteit Maastricht
Prof. dr. A.E.R. Bos, Open Universiteit
Dr. G-J. de Bruijn, Universiteit van Amsterdam

CONTENT

CHAPTER 1

GENERAL INTRODUCTION

GENERAL INTRODUCTION

The world faces a rapid and accelerating aging of its population (United Nations, 2015; National Institute on Aging & World Health Organization, 2011). The number of older persons is growing faster than the numbers of people in any other age group (United Nations, 2015). This process is also taking place in the Netherlands, where the percentage of adults aged 65 years or older in the total population increased from 14% in 2000 to 16% in 2012 (Rijksinstituut voor Volksgezondheid en Milieu, 2014), and will rise to an expected 24% in 2030 and 26% in 2040 (Centraal Bureau voor de Statistiek, 2017). This growth will have large economic impact. Since the prevalence of many chronic health conditions increases with age, health care costs are expected to rise (Denton & Spencer, 2010). Adopting a physically active lifestyle is a factor that could limit this economic impact (Ding et al., 2016), as engaging in regular physical activity (PA) lowers the risk of many health problems, such as cardiovascular disease, type 2 diabetes mellitus, osteoporosis, some cancers, and overweight (e.g. Hamer, Lavoie, & Bacon, 2014; Lee et al., 2012; Reiner, Niermann, Jekauc, & Woll, 2013; Rhodes, Janssen, Bredin, Warburton, & Bauman, 2017; Vogel et al., 2009). Specifically for older adults, other positive outcomes of PA include maintenance of mobility (Pahor et al., 2014; Visser, Pluijm, Stel, Bosscher, & Deeg, 2002) and independent living (Paterson & Warburton, 2010; Vermeulen, Neyens, Van Rossum, Spreeuwenberg, & De Witte, 2011), prevention of falls (Sherrington, Tiedemann, Fairhall, Close, & Lord, 2011; Thibaud et al., 2012) and age-related loss of muscle strength (Cruz-Jentoft et al., 2014; Seco et al., 2013), less risk of cognitive decline and neurodegenerative diseases (Bherer, Erickson, & Liu-Ambrose, 2013; Sofi et al., 2011), and improved health-related quality of life (Motl & McAuley, 2010; Rejeski & Mihalko, 2001).

Because of these numerous health benefits public health guidelines state that all adults should be at least moderately physically active for at least 30 minutes per day on at least five days per week (Haskell et al., 2007; Garber et al., 2011). Worldwide, 69% of all adults do meet this recommended level of PA (Hallal et al., 2012). Most studies in adults aged 60 years or older report that 20-60% of the samples meet the PA guideline (Sun, Norman, & While, 2013). Great variation in frequency of sufficient PA in adults exists between regions, with sufficient PA being more common in countries of low income than in those of high income (Hallal et al., 2012; Sallis et al., 2016). Temporal trends in adults' PA in high income countries show that leisure-time PA levels tend to increase over the past 20-30 years, while work-related PA seems to be decreasing over time (Knuth & Hallal, 2009). Whereas the increase in leisure-time PA may be a consequence of growing awareness of the health benefits of PA, mechanization of labor is probably responsible for the decrease in work-related PA (Knuth & Hallal, 2009). Data for time

trends in PA from low income countries are virtually inexistent (Hallal et al., 2012; Knuth & Hallal, 2009). Temporal trends in the Netherlands over the past 15 years show rising percentages of adults that meet the PA guideline (TNO, 2015). The observed increases, however, tend to be smaller in recent years (TNO, 2015). In the Netherlands, 60% of the adults aged 45 to 65 and 69% of the adults aged 65 or older, are currently sufficiently physically active (Centraal Bureau voor de Statistiek, 2016). Although this statistic seems to be contradictory to the consistent finding in PA epidemiology that PA declines with age (Sun et al., 2013), it may, at least in part, be explained by the milder categorization of light, moderate, and vigorous activities as expressed in energy expenditure that is applied for older adults (see Kemper, Ooijendijk, & Stiggelbout, 2000; Wendel-Vos & Schuit, 2004). Higher percentages of meeting the PA guideline are observed among Dutch adults who are employed and/or not obese. Among Dutch adults aged 65 years or older those with a higher level of education, a lower body mass index (BMI), and/or a lower age more often meet the PA guideline (TNO, 2015). This latter finding shows that the oldest older adults, are at high risk for becoming insufficiently physically active (Sallis et al., 2016).

Despite increasing percentages of older adults that meet the recommended PA level, a large proportion of older adults are currently insufficiently active (Centraal Bureau voor de Statistiek, 2016; Hallal et al., 2012; Sun et al., 2013). Consequently, they will probably miss the large health gains of PA. Promoting PA in older adults is therefore of major relevance. Insight into the psychological factors and processes underlying regular PA is crucial for developing effective interventions to help older adults adopt and maintain a physically active lifestyle (Bartholomew, Parcel, Kok, Gottlieb, & Fernández, 2011; Brug, Oenema, & Ferreira, 2005; Glanz & Bishop, 2010; Michie & Johnston, 2012). The association with older adults' PA has been mapped for many determinants (King, 2001; McKee, Kearney, & Kenny, 2015; Notthoff, Reisch, & Gerstorf, 2017; Van Stralen, De Vries, Mudde, Bolman, & Lechner, 2009a; Van Stralen, Lechner, Mudde, De Vries, & Bolman, 2010), such as age, health status, perceived access to facilities, self-efficacy, intention, and action planning. Nevertheless, there are several other promising determinants that merit examination (Van Stralen et al., 2009a, 2010). One such determinant is habit. The potential importance of habit lies in its particularly close ties to behavior maintenance (Lally, Chipperfield, & Wardle, 2008; Rothman, Sheeran, & Wood, 2009; Verplanken & Wood, 2006), which, in turn, is essential for obtaining many health benefits (Sarafino & Smith, 2014). In order to contribute to further insight, this thesis aims to examine the relationship between habit and PA.

DUAL-PROCESS VIEWS

In health psychology the social cognition approach has been predominant for years (Hagger, 2016). In this approach health behavior is considered to be the result of a rational decision-making process that consists of deliberative and systematic evaluations of available information (Conner & Norman, 2005). Hence, the focus of the social cognition approach is on cognitive precursors of health behavior, such as intentions and goals (Sheeran, Gollwitzer, & Bargh, 2013). It is assumed that these cognitions explain and predict behavior and that changes in these cognitions will engender changes in behavior (Conner & Norman, 2005). However, the social cognition approach has been criticized for providing an insufficient account of health behavior, as it exclusively focuses on rational reasoning (Gibbons, Houlihan, & Gerrard, 2009; Sheeran et al., 2013) and thereby neglects that health behavior often also seems to be guided by implicit, nonconscious influences (Hofmann, Friese, & Wiers, 2008; Hollands, Marteau, & Fletcher, 2016; Marteau, Hollands, & Fletcher, 2012). Recognizing the influence of both explicit cognitions (e.g. intentions) and implicit processes (e.g. habits) on behavior within a single theory is the central element of dual-process theories (Evans, 2008; Hagger, 2016; Quinton & Brunton, 2017). Several dual-process theories have been proposed (e.g. Fazio, 1990; Hofmann et al., 2008; Kremers et al., 2006; Strack & Deutsch, 2004) and applied to a variety of health behaviors, such as sedentary behavior (Conroy, Maher, Elavsky, Hyde, & Doerksen, 2013; Maher & Conroy, 2016), sugar and candy consumption (Hagger, Trost, Keech, Chan, & Hamilton, 2017; Hofmann, Rauch, & Gawronski, 2007; Naughton, McCarthy, & McCarthy, 2015), drinking behavior (Houben & Wiers, 2009; Wiers et al., 2007), smoking cessation (Chassin, Presson, Sherman, Seo, & Macy, 2010), and condom use (Ellis, Collins, Homish, Parks, & Kiviniemi, 2016).

The general critique on the social cognition approach finds an echo in the PA domain (Rebar et al., 2016). A meta-analysis of experimental studies found only a weak relationship between changes in intention and subsequent changes in PA (Rhodes & Dickau, 2012). The changes in PA from corresponding changes in intention were even smaller than those reported for an aggregate of health behaviors (Webb & Sheeran, 2006). Whereas the meta-analysis of Rhodes and Dickau (2012) did not target a specific social cognition model, other meta-analyses have only included applications of the theory of planned behavior (TPB; Ajzen, 1991) to PA. The TPB model has been the leading social cognition model of the last decades (Sniehotta, Presseau, & Araújo-Soares, 2014). The model posits that behavior is directly predicted by intention and perceived behavioral control. Meta-analyses have revealed that intention and perceived behavioral control on average explain 24-36% of variance in PA (Godin & Kok, 1996; Hagger, Chatzisarantis, & Biddle, 2002; McEachan, Conner, Taylor, & Lawton, 2011). This

moderate percentage lends support to the critique that the variables in the TPB model do not give a sufficient account of PA (Conner & Armitage, 1998; Sniehotta et al., 2014). In parallel to the general call for dual-process views on health behavior, it is proposed that a more comprehensive understanding of PA can be achieved by recognizing both explicit and implicit influences on PA (Hagger & Chatzisarantis, 2014). Some studies have applied dual-process views on PA and provide support for the influence of both explicit and implicit processes on PA (e.g. Allom, Mullan, Cowie, & Hamilton, 2016; Arnautovska, Fleig, O'Callaghan, & Hamilton, 2017; Conroy, Hyde, Doerksen, & Ribeiro, 2010; Keatley, Clarke, & Hagger, 2012; Rebar, Elavsky, Maher, Doerksen, & Conroy, 2014).

In general, implicit processes in dual-process views involve automatic and low-effort processes such as relying on heuristic judgment rules (i.e. frugal, efficient rules to quickly solve complex judgmental operations by focusing on some aspects of a situation and ignoring others; Gigerenzer, 2008), goal priming (i.e. unconsciously short exposure to external cues that activate a mental representation of a goal and possibly affect instigation of goal-directed behavior; Papies, 2016), implicit attitudes (i.e. automatic affective responses to attitude objects, which may guide behavior; Friese, Hofmann, & Wänke, 2008; Krishna & Strack, 2017), and habits (Gardner, 2015). The feature that distinguishes habits from other implicit processes is their supposed tight connection to behavior maintenance, which, in case of many health behaviors, is essential for obtaining a wide variety of health benefits (Sarafino & Smith, 2014). The concept of habit has often been used to predict and explain health behaviors (Gardner, 2015), including PA (e.g. Rhodes & De Bruijn, 2010; Rhodes, De Bruijn, & Matheson, 2010). Although it is consistently shown that PA has a habitual component (Gardner, De Bruijn, & Lally, 2011; see section 'Habit and PA' for more details), more research is required to further establish and unravel the relationship between social cognition models, habit, and PA.

WHAT IS A HABIT?

It is often said that people are creatures of habit. To some extent this characterization seems justified, as somewhere between one-third and half of people's everyday actions is habitual (Wood, Quinn, & Kashy, 2002). But what exactly are habits? Habits have been defined as psychological dispositions to repeat past behavior (Neal, Wood, Labrecque, & Lally, 2012). Habits emerge from consistent repetition of behavior in a stable context (Danner, Aarts, & De Vries, 2008; Kaushal & Rhodes, 2015; Lally, Van Jaarsveld, Potts, & Wardle, 2010), whereby control over the behavior is gradually transferred from deliberative thoughts to contextual cues (Lally, Wardle, & Gardner, 2011), such as characteristics of the physical environment, other people, and preceding actions

in a sequence (Wood & Rünger, 2016). As a result these contextual cues acquire the potential to activate behavior, so that upon encountering these stimuli, automatic, habitual responses are activated (Bargh, 1994; Orbell & Verplanken, 2010; Wood & Neal, 2009). Once habits have become strong, the responses no longer depend on supporting intentions and should thus persist even when motivation or self-control resources are lowered (Gardner, 2015; Neal, Wood, & Drolet, 2013); the habitual responses are performed in the absence of conscious control or mental effort (Verplanken, 2006; Wood et al., 2002). As a consequence habits ensure long-term maintenance of behavior (Lally et al., 2008; Rothman et al., 2009; Verplanken & Wood, 2006), which, in case of PA, will ultimately result in health gains.

HABITS IN BRIEF HISTORICAL PERSPECTIVE

The concept of habit has a longstanding philosophical tradition, in which famous philosophers, such as Aristotle, Spinoza, and Hume, formulated opinions on this subject and tried to capture its fundamental properties (see Carlisle, 2014). In the early years of modern psychology, William James (1890) recognized the important role that habits play in people's everyday lives. James (1890) identified features of habits, such as a history of repetition, cue-dependency, and absence of conscious control, that are still present in today's descriptions of habit. These particular features ensured strong ties of habit to behaviorism (Watson, 1913), with its traditions of Thorndike's (1911) laws of effect and exercise and Skinner's (1938) operant conditioning, and its focus on observable stimuli and responses and eschewing of unobservable internal mediating processes (Watson, 1913). Deviating from the most radical version of this paradigm, Hull (1943) postulated habit-mediated responses in his drive theory. In this theory habit is considered an 'invisible condition' (Hull, 1943, p. 21) which strength is supposed to increase progressively, but asymptotically, with the number of reinforcements. Reinforcement-based models, however, were carefully supplanted by more cognitive perspectives (Wood & Rünger, 2016), such as those of Tolman (1948), who proposed that learning does not consist in cue-response connections, but in the building up of internal representations, or cognitive maps, of situations. After the critique of Chomsky (1959) that behaviorism fell short in adequately explaining complex human behavior, a rapid development was noticed in cognitive psychological research, in which causes for behavior were no longer located in the environment, but in internal mental processes (Wood & Neal, 2007). In the following era of cognitive psychology, only scarce attention was paid to the concept of habit. Early dual-process views on information-processing (Schneider & Shiffrin, 1977; Shiffrin & Schneider, 1977; Wason & Evans, 1974) sparked renewed psychological interest in habits (Wood & Rünger, 2016). In line with this

revived interest, Triandis (1977) contended, in his theory of interpersonal behavior, that behavior is a function of habits, intentions, and facilitating factors. This theory assumed that habit was reflected well by the number of times a particular behavior had already occurred (Triandis, 1977). This measure, however, turned out to be inadequate (Eagly & Chaiken, 1993), as frequency does not distinguish between deliberative and habitual action (Ajzen, 2002; Verplanken, 2006). Progress in psychological habit research has long been constrained by this measurement problem (Lally & Gardner, 2013). Perspectives for habit research only emerged when new measurement instruments for habits were developed at the end of the 20th century.

MEASUREMENT OF HABIT

Habit research depends on reliable and valid measures of habit (Gardner, 2015). Several habit measures have been proposed in the last two decades. The four most widely used measures include association measures (e.g. Verplanken, Aarts, Van Knippenberg, & Van Knippenberg, 1994), the Behavior Frequency x Context Stability measure (BFCS; Wood, Tam, Guerrero Witt, 2005), the Self-Report Habit Index (SRHI; Verplanken & Orbell, 2003), and the Self-Report Behavioral Automaticity Index (SRBAI; Gardner, Abraham, Lally, & De Bruijn, 2012b). All measures have their own strengths and weaknesses.

Association measures neither involve behavioral frequency, nor rely on retrospective introspection (Verplanken et al., 1994), but instead tap automaticity (Verplanken, Aarts, & Van Knippenberg, 1997). Association tasks have mainly been applied to the domain of travel mode choices (e.g. Verplanken et al., 1994; Verplanken, Aarts, Van Knippenberg, & Moonen, 1998; Danner et al., 2008). In these tasks participants are presented short statements that globally indicate imaginary everyday trips that vary in distance and destination. After each statement participants are asked to indicate as quickly as possible what mode of transportation they would choose in that particular situation (Verplanken et al., 1998). Higher frequencies of choices for a particular travel mode across stimulus destinations are supposed to reflect a stronger habit (Verplanken et al., 1997, 1998). The benefit of association measures is that they bypass the subjectivity that is inherent to self-reports (Gardner, 2015). Association measures, however, can only be administered in controlled laboratory conditions, which renders them inappropriate for surveys (Verplanken & Orbell, 2003; Gardner, 2015). Moreover, associations measures have been criticized for measuring generalized intentions or prior behavior generalized across situations, rather than habits (Ajzen, 2002).

Drawing on Ouelette and Wood's (1998) argument that habits form when behavior is frequently enacted in stable contexts, Wood et al. (2005) developed the BFCS, in which habit strength is calculated by multiplying measures of self-reported past behavioral frequency and stability of performance context, typically specified as location, time, presence of others or mood (e.g., Ji & Wood, 2007). In several studies this measure has been used to operationalize habit (e.g. Danner et al., 2008; Galla & Duckworth, 2015; Quinn, Pascoe, Wood, & Neal, 2010). However, Gardner (2015) noted two major shortcomings of the BFCS. First, the measure relies on a limited set of cues that is generated by researchers, whereas it has been suggested that cues triggering habits can be anything (Verplanken, 2005). Second, by its focus on stability of a performance context the BFCS assesses the likelihood that a habit has formed instead of the automaticity with which a habitual response is performed.

A habit measure that can easily be incorporated into surveys is the SRHI (Verplanken, Myrbakk, & Rudi, 2005). This measurement instrument was developed to directly capture the automated experience of habitual behavior (Verplanken & Orbell, 2003). By using 12 items the SRHI comprises three dimensions of habit: automaticity, a history of repetition, and self-identity (Verplanken & Orbell, 2003). The automaticity items target a lack of control and intentionality, a lack of awareness, and high mental efficiency (cf. Bargh, 1994). Although the SRHI is the most frequently used measure of habit (Gardner, 2015), it has met with a threefold criticism. First, the SRHI assesses its central characteristic (i.e. automaticity) together with its antecedent (i.e. repetition) and a possible consequence (i.e. incorporation into self-identity), which may bias habit-behavior relationships (Sniehotta & Presseau, 2012). Although repetition items may be needed to distinguish habits from other automatic behaviors, such as behaviors prompted by implementation intentions (Gardner, Abraham, Lally, & De Bruijn, 2012a), self-identity indeed may not be a necessary component of habit (Gardner, De Bruijn, & Lally, 2012). Second, the SRHI does not discern habitual initiation and habitual execution of behavior (Gardner, Phillips, & Judah, 2016; Phillips & Gardner, 2016). Third, as SRHI-items do not refer to contextual cues, the SRHI is supposed to reflect a behavior performed across contexts (Sniehotta & Presseau, 2012). However, the stem of SRHI-items can easily be modified to specify context cues and to distinguish between habitual instigation and execution (Gardner, 2015).

Gardner (2012) advocates that automaticity, and not a history of repetition or self-identity, is habit's core element. Based on this theorizing the SRBAI was suggested as an alternative to the SRHI (Gardner et al., 2012b). The SRBAI consists of four automaticity items taken from the eight item automaticity subscale of the SRHI. The SRBAI is consequently more parsimonious than the SRHI (Gardner et al., 2012b). However, like other habit measures

the SRBAI has also received several critiques. It has been argued that a higher degree of validity is obtained when, in addition to automaticity, other defining characteristics of habits (i.e. repetition and self-identity) are used to capture habits (Orbell & Verplanken, 2015). Furthermore, the SRBAI, like the SRHI, requires respondents to report on aspects of their behavior that are automatic and, as such, outside of conscious awareness (Labrecque & Wood, 2015). This implies that self-reports, rather than reflecting the habit itself, mainly reflect inferences about a particular behavior based on the consequences of that same behavior (Sniehotta & Presseau, 2012). These inferences may be inaccurate (Hagger, Rebar, Mullan, Lipp, & Chatsizarantis, 2015).

Before all habit measures discussed above were developed, Eagly and Chaiken (1993) concluded that it is difficult to design adequate measures of habit. There has been much progress in development of habit measures since this conclusion was drawn. However, given the existing critiques on every habit measure, Eagly and Chaiken's (1993) conclusion still holds true today.

Is there a best habit measure? The choice of a habit measure depends on the goal of the measurement (Verplanken et al., 2005). The studies in this thesis aim to measure the degree to which PA is habitual. For that purpose the SRHI (Verplanken & Orbell, 2003), or shortened scales of this instrument (Orbell & Verplanken, 2015), are probably the better measures (Verplanken et al., 2005), as well as the SRBAI (Gardner et al., 2012b). Both the SRHI and the SRBAI are therefore used in this thesis. In addition, due to unavailability of data on all items from the SRHI and SRBAI in one of the datasets (see section 'Aims and outline of this thesis' for more details about the origin of datasets), habit was also assessed in two substudies in this thesis using an ad hoc measure that consists of four SRHI-items that tap automaticity. This ad hoc measure resembles the SRBAI, as these two four-item measures have two items in common and both focus on automaticity. Other habit measures are not or less eligible: whereas the use of questionnaires in this thesis precludes association tasks, the broad range of physical activities and the vitually endless number of accompanying possible cues impedes the use of the BFCS (Wood et al., 2005).

HABIT AND PHYSICAL ACTIVITY

The concept of habit has been employed across many fields, ranging from environmentally sustainable behavior (e.g. Kurz, Gardner, Verplanken, & Abraham, 2015; Verplanken & Roy, 2015), to continued use of information technology (e.g. Lee, 2014; Wu & Kuo, 2008), consumer behavior (e.g. Olsen, Tudoran, Brunsø, & Verbeke, 2013; Wood &

Neal, 2009), and clinical psychological behavior, such as depressive rumination (Watkins & Nolen-Hoeksema, 2014) and obsessive-compulsive behavior (Ferreira, Yücel, Dawson, Lorenzetti, & Fontenelle, 2017). Applications of the habit concept in the domain of health psychology have shown habitual components for many health behaviors, such as alcohol consumption (Norman, 2011; Albery, Collins, Moss, Frings, & Spada, 2015), fruit consumption (De Bruijn, 2010; De Bruijn, Keer, Conner, & Rhodes, 2012), dental flossing (Hamilton, Orbell, Bonham, Kroon, & Schwarzer, 2018; Judah, Gardner, & Aunger, 2013), and PA (Rhodes & De Bruijn, 2010; Kaushal, Rhodes, Spence, & Meldrum, 2017). The habitual component of PA manifests itself in at least three ways. First, PA correlates moderately to strongly with habit (Gardner et al., 2011). Second, habit typically explains additional variance in PA over and above intentions (e.g. Rhodes & De Bruijn, 2010). Third, habit moderates the influence of intention on light or moderate PA; intention becomes less predictive of PA as habit strength increases (Gardner et al, 2011). However, as a great deal of studies on the relationship between habit and PA used cross-sectional designs and employed student samples (Gardner et al., 2011), this thesis aims at gaining additional insight by replicating and extending the findings above in longitudinal studies in older adult samples.

AIMS AND OUTLINE OF THIS THESIS

The overall aim of this thesis is to unravel longitudinal relationships between habit and PA. The studies of this thesis target three potential roles of habit in relation to PA: habit as moderator (Chapter 2), habit as mediator (Chapter 3 and 4), and habit as outcome variable (Chapter 4 and 5). The first two studies of this thesis (Chapter 2 and 3) are concerned with habit's relationship to the TPB (Ajzen, 1991) and the attitude-social influences-efficacy model (ASE; De Vries, Backbier, Kok, & Dijkstra, 1995; De Vries, Dijkstra, & Kuhlman, 1988), while predicting PA. As the ASE model is largely comparable to the TPB, both models are used without distinction throughout this thesis (see Chapter 2 for more information). The TPB/ASE model has been the dominant social cognition model of the last decades (Sniehotta et al., 2014). Although its parsimoniousness is a huge advantage of the TPB/ASE (Conner, 2015), it has often been questioned whether the constructs in the TPB/ASE give a sufficient account of behavior, or that other constructs should be added (e.g. Conner & Armitage, 1998; Sniehotta et al., 2014). The TPB/ASE does not preclude addition of new determinants (Ajzen, 1991, 2015a; De Vries et al., 1988, 1995; Fishbein & Ajzen, 2010). Habits have been suggested as additional constructs to the TPB/ASE (De Bruijn, Kremers, Singh, Van den Putte, & Van Mechelen, 2009; Schwarzer, 2015). The first two studies build on this suggestion by examining the moderating and mediating role of habit when predicting PA in the context of the TPB/ASE.

The first study of this thesis (Chapter 2) examines whether habit strength moderates the longitudinal intention-PA relationship, within the framework of the TPB/ASE. In other words, the study investigates whether habit strength poses a constraint on the predictive value of intentions for PA. It is hypothesized that a significant intention-PA relationship exists at lower levels of habit strength, but not at higher levels of habit strength. Although this hypothesis has already been confirmed in other studies (see Gardner et al., 2011), it has neither been tested before in an older adults sample, nor in a longitudinal design as applied in this study (i.e. with a six month time lag).

The second study of this thesis (Chapter 3) is grounded in the consistent finding that prior behavior is a good predictor of later behavior, even after TPB/ASE variables have been taken into account (Ajzen, 2011b; De Vries et al., 1995; Sutton, 1994; Triandis, 1977); a finding that also applies to PA (Hagger et al., 2002; McEachan et al., 2011). Habit has often been proposed as a mediating variable between prior and later behavior and, as such, as an explanation of why prior behavior is such a good predictor of later behavior (e.g. Aarts, Verplanken, & Van Knippenberg, 1998; Sutton, 1994; Verplanken, 2006). In the second study of this thesis the hypothesis is set that habit is a mediator of the relationship between prior and later PA.

Both abovementioned studies target intentional and habitual influences when predicting PA. These studies contribute to a more complete insight into determinants of PA and their interplay. Moreover, although departing from different research questions, confirmation of the hypotheses in both studies would imply incorporating habit into the TPB/ASE for, at least, PA, thereby transforming the social cognitive TPB/ASE into a dual-process model. From an interventionist perspective this would imply that habits should be taken into account when developing interventions based on this model.

The longitudinal relationship between habit and PA is unraveled in more depth in the third study of this thesis (Chapter 4). Habit theory states that performing behavior as a habitual response to contextual cues strengthens existing habits until habit strength asymptotically reaches a plateau (i.e. a stable level of habit strength; Lally et al., 2010). Thus, whereas the second study of this thesis hypothesizes that habit mediates the relationship between prior and later PA, it can also be hypothesized that PA mediates the relationship between prior and later habit; a hypothesis that, to our knowledge, has never been tested before. In the third study of this thesis both mediation hypotheses (i.e. a habit-PA-habit path and a PA-habit-PA path) are tested simultaneously using a cross-lagged panel design. This study contributes to a solid theoretical foundation of the interplay between habit and PA by extending current knowledge about longitudinal mediated relationships between habit and PA.

From the second and third study (Chapter 3 and 4) of this thesis follows that the longitudinal relationship between habit and PA can be approached from two different, but interrelated, perspectives: one in which PA is affected by habit and one in which habit is affected by PA. The majority of interventions to stimulate and maintain PA take the latter perspective, but fail to target habit formation explicitly (Lally et al., 2008). Instead, they assume that once intentions are translated into behavior, the behavior will gradually become habitual (Lally et al., 2008). The fourth study of this thesis (Chapter 5) examines whether there is a working mechanism of intention affecting habit through PA.

The fourth study also tries to disentangle the relationship between intention and habit further by examining two other possible mediation effects. It is known that many people fail to act upon their intentions (Sheeran, 2002). As behavioral repetition is a prerequisite for habit formation, not acting upon intentions hinders habit formation. Action planning (AP) is supposed to facilitate the translation of intentions into behavior initiation (Scholz, Schüz, Ziegelmann, Lippke, & Schwarzer, 2008) and behavior repetition (Hagger & Luszczynska, 2014). Repetition of behavior, as a result of AP, may lead to habit formation (Lally et al., 2010; Verplanken, 2005; Wood & Neal, 2009). The fourth study of this thesis therefore also tests whether the relationship between intention and habit is mediated by AP as a single mediator and by AP and PA as sequential mediators. The hypothesis is that significant mediation effects exist for all three mediation paths (i.e. intention-PA-habit, intention-AP-habit, and intention-AP-PA-habit paths).

This thesis concludes with a general discussion (Chapter 6) in which main findings are summarized, implications for theory and practice are discussed, and future directions for research are given.

All studies in this thesis used data from two clustered randomized controlled trials (RCT) in older adults. The first of these RCT's tested the efficacy of two tailored interventions aimed at promoting PA and long-term maintenance of PA in adults, aged 50 years or older (see Van Stralen, De Vries, Mudde, Bolman, & Lechner, 2009b, 2011). The second RCT aimed to compare the effectiveness and cost-effectiveness of four tailored PA interventions for adults aged 50 years or older (see Peels et al., 2013, 2014). Whereas all four studies of this thesis use data from the first RCT, only two studies (Chapter 4 and 5) use data from the second RCT.

CHAPTER 2

HABIT AS MODERATOR OF THE INTENTION-PHYSICAL ACTIVITY RELATIONSHIP IN OLDER ADULTS: A LONGITUDINAL STUDY

Rob J.H. van Bree
Maartje M. van Stralen
Catherine Bolman
Aart N. Mudde
Hein de Vries
Lilian Lechner

Psychology & Health, 2013, 28, 514-532. doi: 10.1080/08870446.2012.749476

ABSTRACT

Objectives: This longitudinal study examined whether habit strength moderates the intention-physical activity (PA) relationship in older adults, within the framework of the theory of planned behavior (TPB) and the attitude-social influences-efficacy (ASE) model.

Methods: A total of 1836 older adults (M_{age} = 62.95 years, *SD* = 8.17) completed a questionnaire on social cognitive constructs and PA habit strength at baseline, and six months later a measure of PA. Three PA habit groups (i.e. low, medium, and high) were composed, based on tertiles of the mean index score.

Results: Multi-group structural equation modeling analyses showed that intention only significantly determined PA behavior in participants with a low or medium habit strength towards PA.

Conclusions: PA is not intentional at high levels of habit strength. It is recommended to incorporate habit into the TPB/ASE model. As strong habits may limit the potential to change PA intentionally, only applying persuasive messaging as an intervention strategy may not suffice, and additional intervention strategies are needed for strongly habitual, but insufficiently active older adults.

INTRODUCTION

Physical inactivity is a modifiable risk factor for health problems such as cardiovascular disease, type 2 diabetes mellitus, osteoporosis, some cancers, and overweight (Bauman, 2004; Chodzko-Zajko et al., 2009; Taylor et al., 2004; Vogel et al., 2009; Warburton, Nicol, & Bredin, 2006). All these health problems have a greater incidence and impact as people age (Department of Health, 2004). Therefore, regular physical activity (PA) is of particular importance for older adults. Despite all the health benefits, only 60% of the people aged 50 years or older in the Netherlands, as in most western countries, meet the international PA recommendation (Centraal Bureau voor de Statistiek, 2010; World Health Organization, 2011) to be at least moderately physically active for at least 30 minutes per day on at least five days per week (Haskell et al., 2007; Nelson et al., 2007). This percentage declines to less than 50% for people aged 75 years or older (TNO, 2007). As future demographic developments will result in larger percentages of older adults in the western world (Christensen, Doblhammer, Rau, & Vaupel, 2009), stimulating PA in this age group is of major importance. To be able to promote PA in older adults, insight into the underlying factors of PA behavioral change, the so-called determinants of PA, is indispensable.

To identify determinants of health behavior, several theoretical models have been used, including the attitude-social influences-efficacy (ASE) model (De Vries, Backbier, Kok, & Dijkstra, 1995; De Vries, Dijkstra, & Kuhlman, 1988) and the theory of planned behavior (TPB; Ajzen, 1991). The ASE model posits that the most powerful and proximal determinant of a certain behavior is the intention to perform the behavior in question. In turn, intention is theorized to be predicted by attitudes (i.e. pros and cons), social influences (i.e. social norms, modeling, and social pressure) and self-efficacy (De Vries et al., 1995). The latter is hypothesized to predict behavior directly. The TPB is largely comparable to the ASE model. Because of the huge similarities both models are used without distinction throughout this chapter. Nonetheless, differences exist between the ASE and the TPB model, since the former uses different terminology (i.e. self-efficacy instead of perceived behavioral control, social norms and modeling instead of injunctive and descriptive norms; see Fishbein & Ajzen, 2010); does not measure attitudes and social influences by multiplicative functions; distinguishes pros and cons within the attitude concept; assesses social influences by not only measuring norms, but also modeling and social support; and suggests the inclusion of previous behavior assessments (De Vries & Mudde, 1998). As yet, many social cognitive models, such as the ASE and TPB models, do not predict health behavior perfectly. Meta-analytic studies on applications of the TPB in a PA context have revealed that attitude, norms, and perceived behavioral control on average explain 42-45% of variance in intention, and that perceived behavioral

control and intention on average explain 27-36% of variance in PA behavior (Godin & Kok, 1996; Hagger, Chatzisarantis, & Biddle, 2002). In order to improve the predictive value of both models, calls have been made to examine the moderating role that some variables might play in cognitions-intention and intention-behavior relations (Cooke & Sheeran, 2004; Conner & Sparks, 2005). In this regard, not only explicit variables need to be emphasized, but also implicit influences, such as factors that automatically trigger behavior. Research on implicit influences as moderators in motivational theoretical frameworks can help to clarify the interplay between explicit and implicit strategies that guide behavior (cf. Strack & Deutsch, 2004). A moderator is a variable that affects the strength of an effect of a predictor variable on a criterion variable (Baron & Kenny, 1986). Thus, the magnitude of this effect depends on the level of the moderator. Identifying moderators can help elucidate the conditions under which a theory works (Conner & Sparks, 2005). In this respect, Triandis (1977, 1980) hypothesized that habit strength forms a boundary condition for intention-behavior relations. Habits are automatically enacted behavioral patterns in response to a context that consistently covaried with past performance (Wood & Neal, 2009). Habitual behavior is cue-induced behavior that does not require conscious control or mental effort. When associated context cues are encountered, automatic, habitual responses are activated (Bargh, 1994). These responses are hypothesized to dominate over deliberative intentions in regulation of behavior. More specifically, the more a certain behavior becomes habitual, the less intention should be able to predict that particular behavior (Triandis, 1977, 1980).

Habits are not only featured by repetition and automaticity, but also by expression of one's identity (Verplanken & Orbell, 2003). A reliable and valid Self-Report Habit Index (SRHI) was developed that taps these features (Verplanken & Orbell, 2003). Recently, full and shortened versions of the SRHI have been helpful in showing a moderation effect that comprises a strong relation between intention and behavior at low levels of habit strength and no relation at high levels of habit strength, in longitudinal studies on moderate PA (Rhodes & De Bruijn, 2010) and travel mode choices (Gardner, 2009), and in cross-sectional studies on active transportation (De Bruijn, Kremers, Singh, Van den Putte, & Van Mechelen, 2009), commuting by bicycle (De Bruijn & Gardner, 2011), sedentary behavior (Kremers & Brug, 2008), and dietary behaviors (De Bruijn, 2010; De Bruijn et al., 2007; De Bruijn, Kroeze, Oenema, & Brug, 2008).

Rhodes, De Bruijn, and Matheson (2010) and Rhodes and Dickau (2013) note that there is a lack of studies focusing on the moderation by habit of the relation between intention and broadly defined moderate PA. It is also noteworthy that most of the abovementioned moderation studies have focused on students, which might call into question the generalizability of the results to other less distinct populations. Only three

studies (i.e. De Bruijn et al., 2008, 2009; Gardner, 2009) targeted somewhat older adults (mean ages varying from 27.5 to 44.3 years). Studies on this issue in older populations (i.e. the over-fifties) are lacking, while PA is of great relevance for older adults, as outlined above. Furthermore, although longitudinal studies have been conducted, the time lags used were short, varying from one week (Gardner, 2009), to two (De Bruijn, Rhodes, & Van Osch, 2012; Rhodes & De Bruijn, 2010; Rhodes et al., 2010) and five weeks (Chatzisarantis & Hagger, 2007).

Since the intention-habit-behavior relationship with regard to PA still leaves some questions and limitations as shown above, the present study was conducted. The purpose of this present study is to perform a structural equation modeling (SEM) analysis to examine whether habit strength moderates the intention-behavior relation with regard to moderate PA in older adults, applying a multi-group longitudinal design with a six month time lag, using the complete SRHI and a broad PA definition (i.e. it includes not only sports, but also everyday activities such as transportation and household activities) that concerns mainly moderate PA. The study is conducted within the framework of the TPB/ASE model, since this will present a thorough view of how automatic versus cognitive prompts of PA behavior work. Moreover, the inclusion of pre-intentional cognitive factors improves the comparability with other similar studies. It is hypothesized that a significant intention-PA relation exists at lower levels of habit strength, whereas this relation is absent at higher levels of habit strength.

METHODS

The study was approved by the Medical Ethics Committee of Maastricht University and the University Hospital Maastricht. Informed consent was obtained from all participants.

Participants and procedures

This study was part of a clustered randomized controlled trial testing the efficacy of two interventions (i.e. a basic intervention targeting psychosocial determinants of PA and a *plus* intervention targeting both psychosocial determinants and PA opportunities in the environment in which the older adults lived) aimed at promoting PA behavior in adults, aged 50 years or older. These interventions proved to be effective in increasing levels of PA at six months (Cohen's *d* effect size $d_{basic} = 0.30$, $d_{plus} = 0.35$) after baseline measurement when compared to control participants (Van Stralen, De Vries, Mudde, Bolman, & Lechner, 2009b). The procedure of the study, including the selection, enrollment, and dropout of participants, the distribution and content of the questionnaires, and the interventions are described in detail elsewhere (see Van Stralen, De Vries, Mudde,

Bolman, & Lechner, 2011; Van Stralen et al., 2008). Participants of both the control group and the two intervention conditions were included in the study in hand (N = 1976). To control for the influence of the interventions, all analyses were adjusted for treatment condition by the use of dummy variables.

Measures

All participants were asked to fill in a questionnaire at baseline and at three, six, and twelve months after baseline measurement, assessing demographics, outcome measures, and theoretical constructs. For the aim of this study, social cognitive constructs from the baseline measurement and PA data from the six months measurement were used.

Items from outcome measures and theoretical constructs referred to sufficient PA, which was explicitly defined as being at least moderately physically active for at least 30 minutes per day on at least five days per week. This definition was repeated three times as a reminder. These reminders were spread proportionally over the questionnaire.

The primary outcome measure was total weekly days of PA, assessed with the self-administered Dutch short questionnaire to assess health enhancing PA (SQUASH) at six months. The overall reliability ($r_{spearman}$ = .57) and relative validity of the SQUASH in relation to Actigraph™ activity monitors ($r_{spearman}$ = .67) were reasonable in older subjects (Wagenmakers et al., 2008). *Total weekly days of PA* was measured using a single item question of the SQUASH: 'On how many days per week are you, in total, at least moderately physically active for at least 30 minutes by undertaking, for example, heavy walking, cycling, chores, gardening, sports or other moderate or vigorous physical activities?' Although single-item self-reports may be less accurate, studies provided support for the validity and reliability of single-item self-reports of PA (Iwai et al., 2001; Jackson, Morrow, Bowles, FitzGerald, & Blair, 2007; Li, Carlson, & Holm, 2000; Milton, Bull, & Bauman, 2011; Weiss et al., 1990). The intercorrelations between the scores obtained from various extensive PA questionnaires and the scores obtained from assessments based on one or two items, are often very low (.15 - .32) for respondents aged 55 years or older (Weiss et al., 1990). The intercorrelation between our single-item score and the total score from the lengthy version of the SQUASH was .41 at six months measurement, thereby exceeding the highest score in the previously mentioned range of .15 - .32.

Social cognitive ASE constructs, which are largely comparable to TPB constructs (see Fishbein & Ajzen, 2010), and habit strength were assessed at baseline. *Pros* and *cons* were assessed with nine and seven items respectively (example of pro/con: 'I find being sufficiently physically active very enjoyable/very time consuming') on five-point Likert scales (-2 = totally disagree; 2 = totally agree). The items were derived from Van Stralen

et al. (2011), who, based on focus group interviews, added eight items to the items by Lechner and De Vries (1995) to cover the concept in more detail. Cronbach's alpha was .86 for pros and .76 for cons. *Social support* was derived from the measurement of Brug, Lechner, and De Vries (1995). It was assessed with one item ('To what degree do people in your direct environment support you to be sufficiently physically active?') on a five-point Likert scale (0 = no support; 4 = much support). Based on Brug et al. (1995), one item was used to assess s*ocial modeling* ('How many people in your direct environment are sufficiently physically active?') on a five-point Likert scale (0 = none; 4 = all). Having a *sports partner* was assessed with one item ('Do you have one or more regular exercise partners?') using a yes (1) or no (0) answer format (Van Stralen et al., 2011). *Self-efficacy* was assessed with ten items (example: 'Do you find yourself able to be physically active for at least 30 minutes per day when you are tired?') on a five-point Likert scale (-2 = definitely not able; 2 = definitely able). The items were based on the questionnaire developed by Resnick and Jenkins (2000) and on focus group interviews with the target group (Van Stralen et al., 2008). Cronbach's alpha was .90. *Intention* to be sufficiently physically active was derived from the measurement of Sheeran and Orbell (1999). It was assessed with three items (example: 'Are you planning to be or to stay sufficiently physically active?') on a ten-point Likert scale (1 = very certainly not; 10 = very certainly yes). Cronbach's alpha was .94.

Habit strength was assessed using the SRHI (Verplanken & Orbell, 2003). All 12 items of this habit strength index were reformulated to suit PA. Participants were asked by means of 12 items to indicate the extent to which they agreed (-2 = totally disagree; 2 = totally agree) with a statement (example: 'Being sufficiently physically active is something I do automatically'). Cronbach's alpha was .93. For the purpose of testing the hypotheses three habit groups were made based on tertiles of the mean index score, resulting in nearly similar group sizes. This approach is preferable to creating habit groups based on one standard deviation from mean, as this would result in unequal group sizes, which in turn would lead to a loss of power (Aguinis & Stone-Romero, 1997). Group size differences were due to ties. Low habit was defined as lower than or equal to .25 (n = 636), medium habit was defined as a habit score between .26 and .82 (n = 554), and high habit was defined as a habit score higher than .83 (n = 646).

For all variables that were measured with more than one item mean scores were calculated. As a consequence, ranges for mean scores are the same as those for the composing items.

Analyses

Multivariate analyses of variance with Tukey-HSD and Games-Howell contrasts were conducted to test for differences in intention and PA between the three habit groups, using SPSS 16.0. Only for this test, mean imputation was used to deal with missing values. SEM analyses were conducted with Mplus 5.21 on a nonimputed data set to test for multi-group differences regarding the intention-behavior relationship, using maximum likelihood estimation to cope with missing values (Muthén & Muthén, 1998-2007).

A combination of fit indices was used to determine model fit. Chi-square tests were conducted to test for differences between theoretical and observed models. A good model fit is indicated by $p > .05$ (Tabachnick & Fidell, 2007). This indicator, however, is most susceptible to large sample sizes. In addition, Root Mean Square Error of Approximation (RMSEA), Comparative Fit Index (CFI), and Tucker-Lewis Index (TLI) were calculated to evaluate the model fit. A good model fit is obtained when RMSEA < .06, CFI > .95 and TLI > .95 (Hu & Bentler, 1999). Furthermore, Akaike Information Criterion (AIC) was used to compare alternative models. The model with the smallest AIC value is chosen as the one with the best and most parsimonious fit (Kline, 2011).

The measurement model and structural models were constructed separately (Byrne, 2012). Pros, cons, self-efficacy, and intention were latent constructs, measured by their separate indicators, as defined in the description of the questionnaire. Confirmatory factor analysis was used to test the measurement model. A minimum factor loading of .40 was used (Stevens, 2002). The adequately defined measurement model was used for the path analyses in the structural model.

Based on the three groups for habit strength, four structural models, consisting of all TPB/ASE relations (see Figure 2.1), were tested. In the first model the three habit groups were constrained to show no differences in the intention-behavior relationship (a-a-a). The Chi-square value for this model served as the baseline value against which the Chi-square values for the other three models were compared. The second model assumed a difference in the intention-behavior relationship between the low and medium habit groups on the one hand and the high habit group on the other (a-a-b). The third model assumed a difference in the intention-behavior relationship between the low habit group compared to both the medium and high habit groups (a-b-b). Last, the fourth model assumed differences in the intention-behavior relationship between all habit groups (a-b-c). Improvement of model fit was tested using the Chi-square difference test, and significance was indicated by $p < .05$. Cohen's effect sizes were used to evaluate the magnitude of the effects (Cohen, 1992).

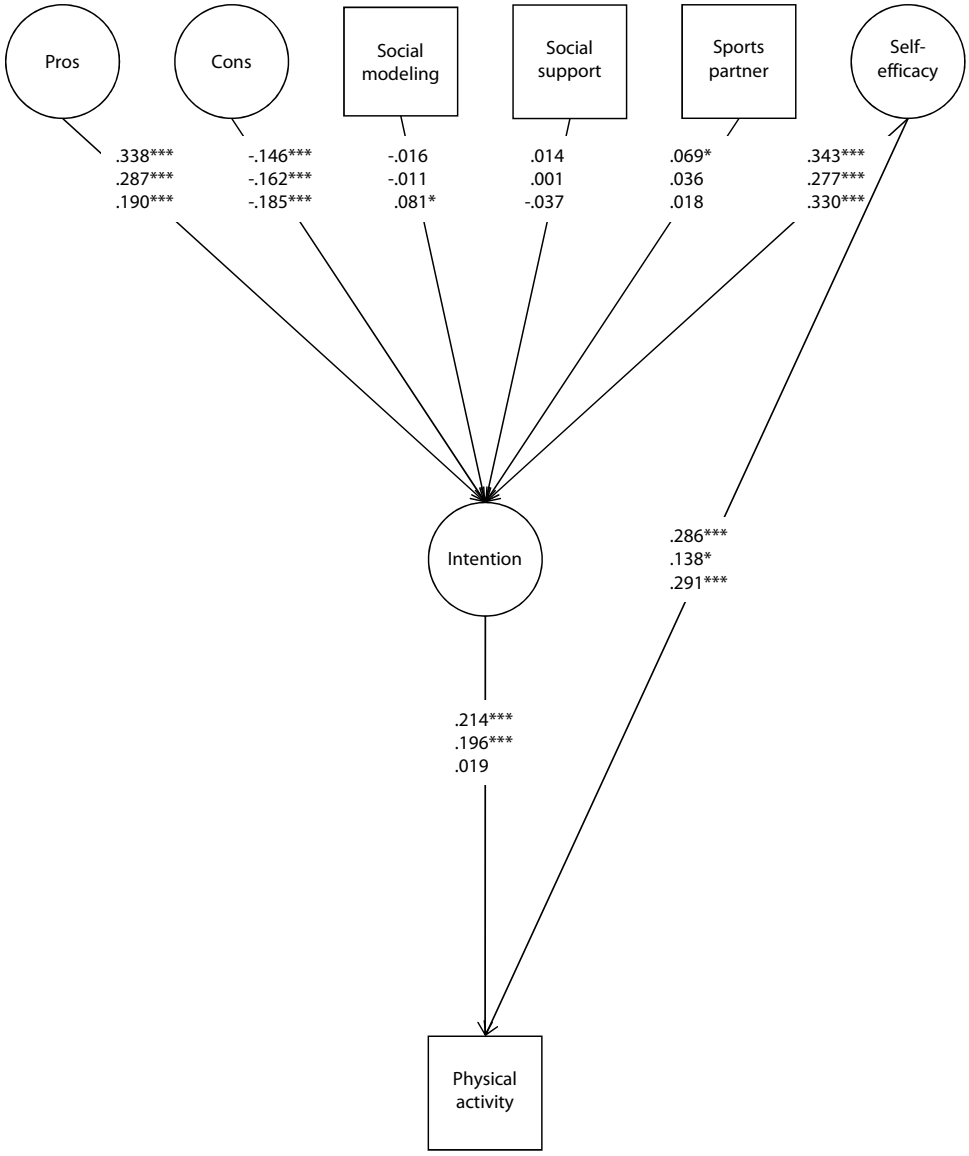

Figure 2.1 Standardized regression coeffcients for model a-a-b

Note. Top values indicate standardized path coefficients for low habit group; middle values indicate standardized path coefficients for medium habit group; bottom values indicate standardized path coefficients for high habit group. For reasons of clarity, dummy variables made to control for treatment condition, are not shown.
Overall model fit: χ^2 (1316) = 2413.75, $p < .001$, CFI = .95, TLI = .94, RMSEA = .04, AIC = 120720.67.
All variables were measured at baseline, except PA, which was measured six months after baseline.
*$p < .05$, **$p < .01$, ***$p < .001$ (one-tailed).

RESULTS

Descriptives

In total, 1976 respondents were included in this study, of whom 140 did not report a habit score and were excluded from the analyses. The mean age of the resulting 1836 participants was 62.95 years (*SD* = 8.17). This group consisted of 534 participants from the control condition, 611 participants from the basic intervention condition, and 691 from the intervention plus condition. Tables 2.1 and 2.2 provide descriptive statistics and bivariate correlations for the study variables in the total group and in the three habit subsamples respectively, based on observed scale means. For the total sample, all correlations predicted by the concepts in the TPB/ASE model were significant, except for the intention-social support correlation. For the three habit groups, the correlation patterns predicted by the TPB/ASE model were significant, except for the intention-social support and intention-social modeling correlation in the low and medium habit group, and for all correlations between intention and social influences in the high habit group. The total group showed a mean habit strength slightly above mid-scale (*M* = .47, *SD* = .74) and a mean intention above mid-scale (*M* = 7.72, *SD* = 1.77). The mean level of PA was 4.63 days per week (*SD* = 1.67). Forty-two percent of the respondents met the recommended level of PA. They were physically active at a moderately or vigorously intensive level for at least 30 minutes per day on at least five days per week.

A multivariate analysis of variance (MANOVA) was performed to investigate habit group differences in intention and PA. Preliminary assumption testing was conducted, with violations of multivariate normality and equality of covariance matrices assumptions noted. These violations do not invalidate the results as a MANOVA is robust to nonnormality when sample sizes are large and equal (Tabachnick & Fidell, 2007) and Pillai's test statistic is robust to heterogeneity when sample sizes are equal (Olsen, 1976). There was a statistically significant difference between the three habit groups, $F(4, 3666) = 107.53$, $p < .001$; Pillai's Trace = .21.

Table 2.1 Descriptive statistics, bivariate correlations and reliability coefficients for total sample

		M	*SD*	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	α
Total sample (*n* = 1836)																
1.	Physical activity	4.63	1.67	-												-
2.	Pros	1.01	.52	.17**	-											.86
3.	Cons	-1.00	.57	-.14**	-.28**	-										.76
4.	Social support	1.55	1.54	-.02	.09**	.06**	-									-
5.	Sports partner	.63	.48	.09**	.20**	-.11**	.16**	-								-
6.	Social modeling	2.22	1.12	.03	.05*	-.04*	.32**	.09**	-							-
7.	Self-efficacy	.57	.66	.30**	.41**	-.35**	-.01	.12**	.09**	-						.90
8.	Intention	7.72	1.77	.29**	.49**	-.38**	.01	.19**	.07**	.52**	-					.94
9.	Habit strength	.47	.74	.29**	.48**	-.26**	-.02	.20**	.12**	.55**	.52**	-				.93
10.	Age	62.95	8.17	-.03	-.17**	.11**	-.04	-.10**	.03	-.14**	-.12**	-.02	-			-
11.	Gender[a]			.07**	.11**	.09**	-.07**	.12**	.09**	.02	.04*	.15**	-.09**	-		-
12.	Intervention[b]			.13**	.00	-.03	.01	-.02	.05*	.05*	.01	.00	-.01	-.00	-	-

Note. Correlation matrix is based on a mean imputed data set; all variables were measured at baseline, except PA, which was measured six months after baseline.
a: 0 = male, 1 = female, n = 1831; b: For reasons of clarity intervention is dichotomized: 0 = no intervention; 1 = intervention.
*$p < .05$, **$p < .01$ (one-tailed).

Table 2.2 Descriptive statistics and bivariate correlations for low, medium, and high habit strength

		M	*SD*	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
Low habit strength (*n* = 636)														
1.	Physical activity	4.06	1.74	-										
2.	Pros	.76	.50	.12**	-									
3.	Cons	-.85	.56	-.08*	-.22**	-								
4.	Social support	1.55	1.48	-.01	.08*	.05	-							
5.	Sports partner	.52	.50	.14**	.17**	-.17**	.20**	-						
6.	Social modeling	2.07	1.09	.03	.06	.02	.35**	.03	-					
7.	Self-efficacy	.17	.70	.21**	.31**	-.29**	.02	.18**	.08*	-				
8.	Intention	6.72	1.86	.25**	.45**	-.34**	.03	.24**	.03	.45**	-			
9.	Age	63.00	8.57	-.04	-.23**	.02	-.06	-.11**	.07*	-.07*	-.10**	-		
10.	Gender[a]			.03	.05	.19**	-.07*	.08*	.04	-.06	-.02	-.15**	-	
11.	Intervention[d]			.15**	-.04	.00	.05	-.00	.05	.02	.02	.07*	.02	-

Continued

Table 2.2 Continued

		M	*SD*	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
Medium habit strength (*n* = 554)														
1.	Physical activity	4.72	1.51	-										
2.	Pros	.99	.45	.06	-									
3.	Cons	-1.00	.52	-.04	-.12**	-								
4.	Social support	1.62	1.57	-.02	.12**	.08*	-							
5.	Sports partner	.66	.47	-.04	.17**	.01	.14**	-						
6.	Social modeling	2.25	1.07	.01	-.02	-.03	.29**	.10**	-					
7.	Self-efficacy	.63	.54	.18**	.20**	-.24**	-.01	-.02	.05	-				
8.	Intention	7.90	1.45	.23**	.35**	-.31**	.02	.08*	-.01	.29**	-			
9.	Age	63.28	8.02	.01	-.16**	.14**	-.04	-.13**	-.04	-.17**	-.11**	-		
10.	Gender[b]			.01	.09*	.17**	-.08*	.07*	.03	-.06	-.04	-.07	-	
11.	Intervention[d]			.18**	-.05	-.06	-.04	-.04	.01	.04	.01	-.03	-.03	-

Continued

Table 2.2 Continued

		M	*SD*	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
High habit strength (*n* = 646)														
1.	Physical activity	5.10	1.57	-										
2.	Pros	1.28	.47	.03	-									
3.	Cons	-1.15	.58	-.12**	-.29**	-								
4.	Social support	1.49	1.57	-.02	.11**	.06	-							
5.	Sports partner	.71	.46	.03	.10**	-.05	.15**	-						
6.	Social modeling	2.34	1.18	-.04	-.03	-.05	.32**	.08*	-					
7.	Self-efficacy	.90	.53	.23**	.29**	-.32**	-.04	-.07*	.02	-				
8.	Intention	8.54	1.41	.12**	.34**	-.34**	-.01	.02	.06	.38**	-			
9.	Age	62.63	7.91	-.03	-.14**	.18**	-.02	-.06	.03	-.25**	-.20**	-		
10.	Gender[c]			.07*	.02	.04	-.04	.13**	.15**	-.04	-.00	-.03	-	
11.	Intervention[d]			.07*	.04	-.01	.03	-.02	.09*	.09*	-.03	-.07*	-.01	-

Note. Correlation matrix is based on a mean imputed data set; all variables were measured at baseline, except PA, which was measured six months after baseline.
a: $n = 635$; b: $n = 552$; c: $n = 644$; a-c: 0 = male, 1 = female; d: For reasons of clarity intervention is dichotomized: 0 = no intervention; 1 = intervention. *$p < .05$, **$p < .01$ (one-tailed).

When the results for the intention to be sufficiently physically active and the PA itself were considered separately, statistically significant differences were found in intention, $F(2, 1833) = 214.13$, $p < .001$, as well as in PA, $F(2, 1833) = 68.90$, $p < .001$. Tukey-HSD and Games-Howell post hoc tests revealed significant differences ($p < .001$) for each comparison between habit groups. The high habit group had a significantly higher intention ($M = 8.54$, $SD = 1.41$) than the medium habit group ($M = 7.90$, $SD = 1.45$), which in turn had a significantly higher intention than the low habit group ($M = 6.72$, $SD = 1.86$). Furthermore, the high habit group showed significantly more PA ($M = 5.10$, $SD = 1.57$) than the medium habit group ($M = 4.72$, $SD = 1.51$), while that group was significantly more physically active than the low habit group ($M = 4.06$, $SD = 1.74$).

The PA recommendation was met by 53.9% of the high habit group, 43.9% of the medium habit group, and 28.9% of the low habit group.

Measurement model

The initial measurement model showed a good model fit, $\chi^2 (350) = 1366.20$, $p < .001$, CFI = .96, TLI = .95, RMSEA = .04, AIC = 112458.73. The significant *p*-value may be due to the large sample size. The model included several residual covariances between items that loaded onto the same latent variable. Furthermore, the model included one pros-item ('Sufficient PA is good for my social contacts') and two cons-items ('Sufficient PA is too time consuming' and 'Sufficient PA increases chances on injuries') with factor loadings < .40, which were removed. The final measurement model yielded a good model fit, $\chi^2 (272) = 855.74$, $p < .001$, CFI = .98, TLI = .97, RMSEA = .03, AIC = 98240.85, with all factor loadings > .40.

Structural models

Estimation with maximum likelihood assumes multivariate normality of the outcome variables (Kline, 2011). Preliminary assumption testing revealed the violation of this assumption. However, this violation does not invalidate the results as maximum likelihood estimation is robust to nonnormality when sample sizes are large (Chou & Bentler, 1995), which is the case in this study.

The first model (a-a-a), in which the three habit groups were constrained to equally influence the intention-PA relationship, showed a good model fit, $\chi^2 (1317) = 2419.40$, $p < .001$, CFI = .95, TLI = .94, RMSEA = .04, AIC = 120724.32. The significant *p*-value may be due to the large sample size. The second model (a-a-b), in which the low and medium habit group were contrasted with the high habit group, had a significantly better model fit than the first model, $\chi^2 (1316) = 2413.75$, $p < .001$, CFI = .95, TLI = .94, RMSEA = .04,

AIC = 120720.67; $\Delta\chi^2$ (1) = 5.65, p = .009 (one-tailed). Contrasting the low habit group with the medium and high habit group (a-b-b) did not improve the model fit compared to the first model, χ^2 (1316) = 2419.19, p < .001, CFI = .95, TLI = .94, RMSEA = .04, AIC = 120726.11; $\Delta\chi^2$ (1) = 0.20, p = .326 (one-tailed). The final model (a-b-c), in which differences were allowed between all three groups, showed a significantly better model fit compared to the first model, χ^2 (1315) = 2413.01, p < .001, CFI = .95, TLI = .94, RMSEA = .04, AIC = 120721.93; $\Delta\chi^2$ (2) = 6.39, p = .020 (one-tailed). The AIC values indicated the most parsimonious fit for the second model (a-a-b)[1], which is shown in Figure 2.1.

In the a-a-b model intention was a significant predictor of PA in the low habit (standardized regression coefficient β = .214, SE = .044, p < .001, one-tailed) and medium habit (β = .196, SE = .041, p < .001, one-tailed) group, but not in the high habit group (β = .019, SE = .060, p = .373, one-tailed)[2]. Self-efficacy was a significant predictor of PA in all habit groups (β = .286, SE = .060, p < .001 for low habit group; β = .138, SE = .060, p = .011 for medium habit group; β = .291, SE = .062, p < .001 for high habit group; all p-values are one-tailed). The model explained 21.4% of the variance in PA in the low habit group, 12.0% in the medium habit group and 10.1% in the high habit group, indicating medium effect sizes (Cohen, 1992).

DISCUSSION

This longitudinal study was, to our knowledge, the first to explore whether habit strength moderates the intention-behavior relationship with regard to broadly defined moderate PA in older adults, within the framework of the TPB/ASE model. Results confirmed the hypothesized moderation. Intention significantly determined PA behavior in participants with a low to medium habit strength towards PA, but not in older adults who had a strong habit. This indicates that PA can be intentional, as well as habitual, depending on the level of habit strength. This result is in line with recent studies in the field of PA that have found a limited effect of intention on behavior when habit is strong (Chatzisarantis & Hagger, 2007; De Bruijn et al., 2009; De Bruijn & Gardner, 2011; De Bruijn & Rhodes, 2011; Gardner, De Bruijn, & Lally, 2011). Furthermore, our finding that the a-a-b model, in which the low and medium habit group were contrasted with the high habit group, showed the most parsimonious fit, replicated the results that De Bruijn et al. (2007) found in a study on fruit consumption. Our results support Triandis' (1977, 1980) notion that habit forms a boundary condition for the intention-behavior relationship, as well as the assumption of dual-process theories that behavior is the result of explicit cognitions (i.e. intentions) and implicit (i.e. habits) processes (e.g.

Kremers et al., 2006). In line with these theories and in order to improve the predictive value of the models, it is recommended to incorporate habit strength into the TPB/ASE model.

This study has several strengths. First, our study was the first to apply a multi-group longitudinal design with a six month time lag in a study on the moderation effect of habit on the intention-PA relationship. Second, our research population consisted of older adults. Insight into the working mechanisms of PA for this growing population may help to design interventions to increase PA in older adults. Third, we performed SEM analyses, instead of regression analyses, which are used most frequently in other studies on habit as a moderator in the PA domain. SEM analyses have the advantage of taking measurement errors into account and providing important additional information about model fit, and thus give a more complete statistical underpinning of the results (Peyrot, 1996). However, some limitations of the present study also have to be addressed. First, a self-report single-item measure of PA was used. Although studies provided support for the reliability and validity of single-item self-reports of PA (e.g. Milton et al., 2011), self-reports may be both higher and lower than true levels of PA (Prince et al., 2008). Second, habit was also assessed using a self-report measure (i.e. SRHI). Although this measurement instrument is reliable and valid (Verplanken & Orbell, 2003), its nature remains subjective. Replicating and validating our results with objective measurements in future research would therefore be recommendable. In addition, the SRHI has recently been criticized for assessing the central characteristic of habit (i.e. automaticity) together with its antecedent (i.e. repetition) and a possible consequence (i.e. incorporation into self-identity), which may bias the habit-behavior relationship (Sniehotta & Presseau, 2012). Gardner, Abraham, Lally, and De Bruijn (2012a) replied to this criticism and contended that repetition indicators within the SRHI are needed to distinguish habits from other automatic behaviors, such as behaviors prompted by implementation intentions. Self-identity may not be a necessary component of habit (Gardner, De Bruijn, & Lally, 2012). Third, the proportion of explained variance in the medium and high habit group was smaller than the variance in PA that is typically explained by habit alone (i.e. around 20%, see Gardner et al., 2011). Although we provided an explicit definition of PA and repeated this definition three times over the questionnaire, this might have been inadequate to ensure that participants kept that definition in mind all the time while interpreting the questionnaire, which may have caused inconsistencies. These inconsistencies could have led to error in the prediction of PA, thereby lowering the proportion of variance accounted for. Fourth, our data stem from an intervention study in which the initial response rate was not very high (i.e. 23%) and dropout was selective (for details and discussion see Van Stralen et al., 2009b, 2011). Although we corrected for possible intervention effects, this issue may

hinder the generalization of the results. Fifth, since research in the habit domain has not yet been able to identify validated cut-off points to differentiate groups with regard to habit strength, we constructed groups based on tertiles, thereby inevitably relying on a data-driven definition.

The findings of the present study have important implications for PA intervention development. Although not a central outcome of this paper, it is noteworthy that self-efficacy proved to be a PA predictor in all habit groups, indicating that confidence in the execution of PA behavior is important. It is recommended to target self-efficacy in PA interventions. However, high self-efficacy does not imply that behavior is intentional. Interventions aimed at increasing PA levels often use persuasive, informational messages on, among other things, health benefits of regular PA, in order to stimulate people to change their PA behavior intentionally into a more healthy direction (e.g. Parrott, Tennant, Olejnik, & Poudevigne, 2008). A prerequisite for this intentional shift towards a more healthy PA pattern is that recipients pay attention to and actively process the content of persuasive messages (Cacioppo & Petty, 1984). Research, however, has indicated that those who are guided by strong habits use automatic, heuristic, and low effort strategies to arrive at decisions, rather than that they extensively process all available information regarding alternative options (e.g. Aarts & Dijksterhuis, 2000; Aarts, Verplanken, & Van Knippenberg, 1997; Wood & Neal, 2009). Persuasive messages may therefore go unnoticed by those with strong habits (Verplanken, Aarts, & Van Knippenberg, 1997). This notion is salient, because in our study about half of the older adults who had a strong PA habit did not meet the recommended level of being at least moderately physically active for at least 30 minutes on at least five days per week. This large proportion of our target population may thus not be persuaded by traditional health communication efforts using persuasive messages. Therefore, other intervention strategies are needed to expand the existing habitual pattern of PA behavior and/or to increase the intensity of PA contained therein. In their review, Lally and Gardner (2013) identify several intervention strategies to expand healthy habitual patterns of insufficient intensity or duration. They mention the use of reminders, self-monitoring and self-control, awareness of cues, implementation intentions, and mental contrasting as effective intervention strategies. It is not always possible to include all these strategies in a single intervention. Nonetheless, when designing health interventions, such as PA interventions in older adults, for whom PA has many health benefits, it is recommended to discern habit subgroups and to adapt the content of interventions to these subgroups.

Two directions for future research need to be mentioned. First, because results indicated that high habitual PA behavior does not automatically go together with a sufficient level of PA, one may question whether people high in habit, but insufficient in level of PA, are aware of their insufficient PA pattern. If these people are unaware, then awareness raising may be a successful supplemental strategy to informational interventions that can be applied when strong habits are disrupted. Second, studies on vigorous exercise in students have yielded contradictory results. Some studies found a strong relation between intention and vigorous exercise at low levels of habit strength, but no relation at high levels of habit strength (Chatzisarantis & Hagger, 2007; De Bruijn & Rhodes, 2011), whereas other studies found no moderation effect at all (Rhodes et al., 2010) or an opposite moderation effect of habit, comprising a stronger intention-exercise relation when habit is strong (De Bruijn, Rhodes et al., 2012; Rhodes & De Bruijn, 2010). To account for these latter results the authors hypothesized that vigorous and effortful exercise may require strong motivational and automatic components simultaneously, in contrast to mild or moderate PA and everyday behaviors, such as fruit consumption or travel mode choices. Nevertheless, the findings of these two latter studies contradict the results of the former three studies on vigorous exercise and our current study on moderate PA. To disentangle the exact nature of the relationship between habit, intention and exercise further research, not only in (relatively young) adult populations (e.g. students), but also in older adult populations, is recommended.

In sum, the present longitudinal study was the first to show that intentional control of PA in older adults depends on the level of habit strength, which has consequences for intervention development.

NOTES

[1] Within the framework of the TPB/ASE model the hypothesis was also tested in a SEM analysis using two interaction terms, namely the linear intention*habit and the nonlinear intention*habit*habit. Only the latter interaction term reached significance with both estimator maximum likelihood (ML) ($B_{intention*habit}$ = -.080, SE = .060, p = .090, one-tailed; $B_{intention*habit*habit}$ = -.105, SE = .039, p = .004, one-tailed) and robust maximum likelihood (MLR) ($B_{intention*habit}$ = -.080, SE = .084, p = .171, one-tailed; $B_{intention*habit*habit}$ = -.105, SE = .054, p = .027, one-tailed). This quadratic association indicates that the effect of intention on PA decreases as habit increases, but this decrease is increasing as habit increases (Kenny, 2011).

[2] The same analyses were conducted for the control group alone. Model fit for the baseline model: χ^2 (1185) = 1695.06, p < .001, CFI = .92, TLI = .91, RMSEA = .05, AIC = 34413.78. Model fit for the a-a-b model was marginally significantly better compared to the baseline model: χ^2 (1148) = 1692.99, p < .001, CFI = .92, TLI = .91, RMSEA = .05, AIC = 34413.70; $\Delta\chi^2$ (1) = 2.07, p = .075 (one-tailed). Standardized regression coefficients for intention in the a-a-b model for low habit: β = .251, SE = .068, p < .001, medium habit: β = .226, SE = .061, p < .001, and high habit: β = .019, SE = .100, p = .424. Model fit for the a-b-b and a-b-c model did not improve compared to the baseline model: $\Delta\chi^2_{a\text{-}b\text{-}b}$ (1) = .89, p = .173 (one-tailed), $\Delta\chi^2_{a\text{-}b\text{-}c}$ (2) = 2.22, p = .165 (one-tailed).

CHAPTER 3

HABIT AS MEDIATOR OF THE RELATIONSHIP BETWEEN PRIOR AND LATER PHYSICAL ACTIVITY: A LONGITUDINAL STUDY IN OLDER ADULTS

Rob J.H. van Bree
Maartje M. van Stralen
Aart N. Mudde
Catherine Bolman
Hein de Vries
Lilian Lechner

Psychology of Sport and Exercise, 2015, 19, 95-102. doi: 10.1016/j.psychsport.2015.03.006

ABSTRACT

Objectives: Habit has been proposed as an explanation of why prior behavior is a good predictor of later behavior. This study examined whether habit mediates the relationship between prior and later physical activity (PA), within the framework of the theory of planned behavior (TPB) and the attitude-social influences-efficacy (ASE) model.

Methods: A total of 1976 older adults (M_{age} = 63.63, SD = 8.66) completed questionnaires on TPB/ASE constructs and PA at baseline, intention at three months, habit at six months, and PA at twelve months.

Results: Path analyses showed that habit significantly mediates the relationship between prior and later PA, after TPB/ASE variables were taken into account.

Conclusions: Habit is a partial solution to the question why prior PA is a good predictor of later PA. It is recommended to incorporate habit into the TPB/ASE model.

INTRODUCTION

Although physical activity (PA) is an important contributor to physical and mental health (e.g. Chodzko-Zajko et al., 2009; Durstine, Gordon, Wang, & Luo, 2013; Vogel et al., 2009), a large proportion of adults aged 50 years or older are currently insufficiently active to obtain the health benefits associated with PA (World Health Organization, 2011). In order to be able to develop effective PA interventions for this age group, insight into the determinants of PA is indispensable. Two theoretical models that describe the processes wherein health behaviors are shaped and that have often been used to guide intervention development, are the attitude-social influences-efficacy (ASE) model (De Vries, Backbier, Kok, & Dijkstra, 1995; De Vries, Dijkstra, & Kuhlman, 1988) and the theory of planned behavior (TPB; Ajzen, 1991).

The ASE model contends that health behavior is governed by intention to act and self-efficacy, while intention, in turn, is determined by attitudes (i.e. pros and cons), social influences (i.e. social norms, modeling, and social support) and self-efficacy (De Vries et al., 1995). The TPB is largely comparable to the ASE model, although small differences do exist (De Vries & Mudde, 1998). One such difference concerns the inclusion of previous behavior in the model. Whereas the ASE model is open to include previous behavior (De Vries et al., 1995; De Vries & Mudde, 1998), the TPB rejects this suggestion, based on the assumption that the influence of prior on later behavior is mediated by the model's constructs (Ajzen, 1991). Nonetheless, both models are used without further distinction throughout this chapter, firstly because both models are conceptually closely related and complete each other in operationalization of the core concepts, and secondly because the research question addressed in this chapter is equally relevant for both models.

Meta-analytic studies on applications of the TPB/ASE model in a PA context have revealed that attitude, social influences and self-efficacy on average explain 42-46% of variance in intention, and that self-efficacy and intention on average explain 24-36% of variance in PA behavior (Godin & Kok, 1996; Hagger, Chatzisarantis, & Biddle, 2002; McEachan, Conner, Taylor, & Lawton, 2011). These numbers, although quite substantial, support the proposition that the variables in the model do not sufficiently predict and explain intentions towards PA and PA behavior (Conner & Armitage, 1998).

Based on the dictum that prior behavior is a good predictor of later behavior (Ajzen, 2011b, Sutton, 1994; Triandis, 1977), prior PA has often been added to the TPB/ASE model to improve prediction of later PA (e.g. Abraham & Sheeran, 2004; Bozionelos & Bennett, 1999; Brickell, Chatzisarantis, & Pretty, 2006; Godin, Valois, & Lepage, 1993;

Jackson, Smith, & Conner, 2003; Norman & Smith, 1995; Wang, 2011). Meta-analyses have shown that prior PA contributes 10-19% (Hagger et al., 2002; McEachan et al., 2011) to the prediction of later PA, in addition to the TPB/ASE variables. These findings contradict the assumption of especially the TPB model that the effect of prior on later behavior is fully mediated by the model's constructs (Ajzen, 1991, 2002). The residual impact of prior behavior has also been demonstrated in other health domains, such as alcohol consumption (Conner, Warren, Close, & Sparks, 1999), breast self-examination (Lechner, De Nooijer, & De Vries, 2004), sleep hygiene (Kor & Mullan, 2011), and breakfast consumption (Wong & Mullan, 2009).

It has been argued that residual effects of prior behavior on later behavior are due to shared method variance, as they are often assessed using the same measurement instrument (Ajzen, 1991, 2002). By contrast, two studies have shown that residual effects of prior behavior also exist when using different measurement instruments, indicating that these effects are not solely attributable to shared method variance (Conner et al., 1999; Verplanken, 2006). Furthermore, a statistical test by Bamberg, Ajzen, and Schmidt (2003) did not provide support for the shared method variance explanation. Should prior behavior thus be interpreted as a variable to be incorporated into the TPB/ASE model? Caution is warranted in giving prior behavior the same status as other TPB/ASE variables (Conner & Sparks, 2005). The TPB/ASE model, namely, is a causal model, meant both to predict and explain behavior (Sutton, 1998). Although it is beyond doubt that prior behavior often has predictive value, it is theoretically inadequate to contend that individuals perform a behavior *because* they have performed it in the past (Conner & Sparks, 2005). On an explanatory level the question thus remains why prior behavior predicts later behavior (Fishbein & Ajzen, 2010). This question is referred to as the *residual variance problem* (Ajzen, 2002).

Habits have often been proposed as a solution to the residual variance problem (e.g. Aarts, Verplanken, & Van Knippenberg, 1998; Sutton, 1994). Habits are defined as automatically enacted behavioral patterns in response to a context that consistently covaried with past performance (Wood & Neal, 2009). Although habits as an explanation of the residual variance problem may sound quite appealing, the mere existence of residual effects of prior on later behavior is not evidence of the existence of habits (Ajzen, 2002). Any configuration of factors that exerted an effect in the past and that continues to influence behavior at present could explain the residual effect (Ajzen & Fishbein, 2000). In order to accept habit as a valid explanation of the residual variance problem, Ajzen (2002) has set the conditions that, first, habit must be measured with a theory-based instrument that does not solely equate habit with past behavioral frequency, and, second, habit must mediate the relationship between prior and later behavior. From a

practical point of view, meeting these two conditions implies incorporating habit into the TPB/ASE model and taking habit into account when developing interventions based on this model.

Although several calls have been made to test habit's hypothesized mediating role in the relationship between prior and later behavior (e.g. Smith et al., 2007), to our knowledge, only two studies conducted this test. In the first study, on travel mode choices, Bamberg et al. (2003) did not find support for the mediation hypothesis. In this study the response frequency measure of habit (see Verplanken, Aarts, Van Knippenberg, & Van Knippenberg, 1994) was used. This measure has been criticized for measuring generalized intentions or prior behavior generalized across situations, rather than habits (Ajzen, 2002). The Self-Report Habit Index (SRHI; Verplanken & Orbell, 2003) overcomes this criticism. This reliable and valid instrument covers three features of habits, namely repetition, automaticity, and expression of one's self-identity. In the second study, Verplanken (2006) used this measure of habit and found that habit mediated the relationship between prior and later snacking behavior. Both mediation studies were based on the causal steps approach (Baron & Kenny, 1986), in which the mediation effect is logically inferred, rather than directly estimated (Hayes, 2013).

The present study aims to perform path analyses to examine whether habit mediates the relationship between prior and later PA within the framework of the TPB/ASE model, applying, in accordance with Hayes' (2013) recommendation, a direct estimate of the mediation effect. It is hypothesized that habit is a mediator of the relationship between prior and later PA.

METHODS

The study was registered at the Dutch Trial Register (NTR920) and approved by the Medical Ethics Committee of Maastricht University and the University Hospital Maastricht. Informed consent was obtained from all participants.

Participants and procedures

This study was part of a clustered randomized controlled trial testing the efficacy of two interventions (i.e. a basic intervention targeting psychosocial determinants of PA and a *plus* intervention targeting both psychosocial determinants and PA opportunities in the environment in which the older adults lived) aimed at promoting PA behavior in adults, aged 50 years or older. These interventions proved to be effective in increasing levels of PA (days per week) at three (Cohen's *d* effect size d_{basic} = .20, d_{plus} = .20), six (d_{basic} = .30,

d_{plus} = .35), and twelve months (d_{basic} = .18, d_{plus} = .18) after baseline measurement when compared to control participants (Van Stralen, De Vries, Mudde, Bolman, & Lechner, 2009b, 2011).

Via six randomly selected Municipal Health Councils, 8500 Dutch adults aged 50 years or older, were invited to participate in the study. A total of 1976 adults (23%) agreed to participate and completed the baseline questionnaire. Of these participants (M_{age} = 63.63, *SD* = 8.66, 43% male, 51% meeting the PA recommendation), 30% were assigned to the control condition, 33% to the basic intervention condition, and 37% to the intervention plus condition. Retention rates at three, six, and twelve months were 74%, 71%, and 68% respectively. The procedure of the study, including the selection, enrollment, and dropout of participants, the distribution and content of the questionnaires, and the interventions are described in detail elsewhere (see Van Stralen et al., 2008, 2011).

Participants of both the control group and the two intervention conditions were included in the present study. To control for the influence of the interventions, all analyses were adjusted for treatment condition by the use of dummy variables. However, in order to eliminate any concern about possible residual intervention effects not controlled for by dummy variables, the analyses were also conducted in the control group alone. Furthermore, the analyses were also carried out in the intervention group alone.

Measures

Data were collected by means of extensive questionnaires at baseline (t0) and at three (t1), six (t2), and twelve (t3) months after baseline measurement (see Van Stralen et al. 2008, 2011 for details). For the current study we used data, taken from these questionnaires, on social cognitive (TPB/ASE) constructs and PA (t0), intention (t1), habit (t2), and, again, PA (t3). The operationalization of the constructs is described below.

Items of outcome measures and social cognitive constructs referred to sufficient PA, which, in accordance with the international PA recommendation for people aged 50 years or older (Haskell et al., 2007; Nelson et al., 2007), was defined as being at least moderately physically active for at least 30 minutes per day on at least five days per week. This definition was repeated several times as a reminder. These reminders were spread proportionally over the questionnaire.

The primary outcome measure was total weekly days of PA, assessed with the self-administered Dutch short questionnaire to assess health-enhancing PA (SQUASH). The overall reliability ($r_{spearman}$ = .57) and relative validity of the SQUASH in relation to Actigraph™ activity monitors ($r_{spearman}$ = .67) were reasonable in older subjects

(Wagenmakers et al., 2008). *Total weekly days of PA (t0, t3)* was measured using a single-item question of the SQUASH: 'On how many days per week are you, in total, at least moderately physically active for at least 30 minutes by undertaking, for example, heavy walking, cycling, chores, gardening, sports or other moderate or vigorous physical activities?' Although single-item self-reports may be less accurate, studies provided support for the validity and reliability of single-item self-reports of PA (Iwai et al., 2001; Jackson, Morrow, Bowles, FitzGerald, & Blair, 2007; Li, Carlson, & Holm, 2000; Milton, Bull, & Bauman, 2011; Milton, Clemes, & Bull, 2013; Wanner et al., 2014; Weiss et al., 1990). The intercorrelations between scores obtained from various extensive PA questionnaires and scores obtained from assessments based on one or two items, are often weak (.15 - .32; Weiss et al., 1990) to moderate (.46 - .54; Milton et al., 2011) for respondents aged 55 years or older. The intercorrelation between our single-item score and the total score from the lengthy version of the SQUASH was .39 at baseline and .41 at twelve months measurement, which can be described as moderate (Cohen, 1988).

Pros and cons (t0) were assessed by nine and seven items respectively (example of pro/con: 'I find being sufficiently physically active very enjoyable/very time consuming'). Answering options ranged from 'totally disagree' (-2) to 'totally agree' (2). Eight items were adapted from items used by Lechner and De Vries (1995). Van Stralen et al. (2011) added another eight items, based on focus group interviews (Van Stralen et al., 2008), to cover the concept in more detail. Cronbach's alpha was .86 for pros and .77 for cons.

Social support (t0) was assessed by one item ('To what degree do people in your direct environment support you to be sufficiently physically active?'). Answering options ranged from 'no support' (0) to 'much support' (4). *Social modeling (t0)* was also measured by one item ('How many people in your direct environment are sufficiently physically active?'). Answering options ranged from 'none' (0) to 'all' (4). Both items are adapted from items used by Brug, Lechner, and De Vries (1995). Having an *exercise partner (t0)* was assessed with one item ('Do you have one or more regular exercise partners?') using a yes (1) or no (0) answer format.

Self-efficacy (t0) was measured by ten items (example: 'Do you find yourself able to be physically active for at least 30 minutes per day when you are tired?'). Answering options ranged from 'definitely not able' (-2) to 'definitely able' (2). The items were based on the questionnaire developed by Resnick and Jenkins (2000) and on focus group interviews with the target group (Van Stralen et al., 2008). Cronbach's alpha was .90.

Intention (t1) to be sufficiently physically active was assessed by three items (example: 'Are you planning to be or to stay sufficiently physically active?'). The items were adapted from the measurement of Sheeran and Orbell (1999). Answering options ranged from 'very certainly not' (1) to 'very certainly yes' (10). Cronbach's alpha was .93.

Habit (t2) was measured using the SRHI (Verplanken & Orbell, 2003). All 12 items of the SRHI were reformulated to suit PA (example: 'Being sufficiently physically active is something I do automatically'). Answering options ranged from 'totally disagree' (-2) to 'totally agree' (2). Cronbach's alpha was .91.

Analyses

Means, standard deviations, and correlations were calculated using Mplus 5.21. Path analyses were conducted with Mplus 5.21 to test for the hypothesized mediation effects, using maximum likelihood estimation to cope with missing values (Muthén & Muthén, 1998-2007).

Whereas conceptual independence of all variables is a premise of the TPB/ASE model, the existence of correlations among variables is an empirical question (Ajzen, 2015b). In their meta-analysis Conner and Sparks (2005) found that the TPB/ASE variables correlate with each other and with behavior. Therefore, in addition to the causal paths from the TPB/ASE model, in the path model covariances were defined among all t0 variables and between PA(t0) and intention(t1). Furthermore, TPB/ASE variables and habit are typically found to correlate in research on exercise (De Bruijn & Rhodes, 2011; De Bruijn, Rhodes, & Van Osch, 2012), commuting by bicycle (De Bruijn, Kremers, Singh, Van den Putte, & Van Mechelen, 2009), and dietary behaviors (De Bruijn et al., 2007; De Bruijn, Kroeze, Oenema, & Brug, 2008; Verplanken, 2006). Therefore, in the path model covariances between habit(t2) and all TPB/ASE variables were defined.

A combination of fit indices was used to determine model fit. Chi-square tests were conducted to test for differences between theoretical and observed models. A good model fit is indicated by $p > .05$ (Tabachnick & Fidell, 2007). This indicator, however, is most susceptible to large sample sizes (Kline, 2011). In addition, Root Mean Square Error of Approximation (RMSEA), Comparative Fit Index (CFI), and Tucker-Lewis Index (TLI) were calculated to evaluate model fit. An adequate model fit is obtained when RMSEA < .08, CFI > .90, and TLI > .90 (Van de Schoot, Lugtig, & Hox, 2012), whereas a good model fit is indicated by RMSEA < .06, CFI > .95, and TLI > .95 (Hu & Bentler, 1999).

The mediation effect was estimated using the product of coefficients test (e.g. MacKinnon, 2008). This method assumes the mediation effects to be normally distributed, which is usually only the case in large samples (Jose, 2013), a prerequisite that is met in the present study. In addition, 95% confidence intervals (CI) based on the distribution of the product were calculated, using RMediation (Tofighi & MacKinnon, 2011). CI's based on the distribution of the product take nonnormality of mediation effects into account. The percentage mediated effect (PME) was used as an effect size to evaluate the magnitude of the mediation effect (see MacKinnon, 2008). PME requires a sample size of at least 500 (MacKinnon, Warsi, & Dwyer, 1995), a criterion that is met in this study. The completely standardized indirect effect ($\hat{a}\hat{b}_{cs}$; Preacher & Kelley, 2011) was also used as an effect size. This effect size was evaluated according to Cohen's r^2 criteria (.01 = small; .09 = medium; .25 = large; Cohen, 1988). The total amount of variance explained in intention(t1) and PA(t3) was calculated and evaluated using Cohen's f^2 effect size (.02 = small; .15 = medium; .35 = large; Cohen, 1988).

RESULTS

Correlations

Means, standard deviations, and maximum likelihood bivariate correlations were estimated (see Table 3.1). All correlations predicted by the TPB/ASE model were significant, except for the intention-social support correlation.

Path models

The path model yielded a good model fit, χ^2 (5) = 17.78, p = .003, CFI = .99, TLI = .94, RMSEA = .04. A significant mediation effect was found for the path PA(t0)-habit(t2)-PA(t3) (product of coefficients' z = 5.14, p < .001, CI = [.04; .08], $\hat{a}\hat{b}_{cs}$ = .06, PME = 19.3%) (see Figure 3.1). The $\hat{a}\hat{b}_{cs}$ indicates a small to medium effect size. The path model explained 30.4% of variance in intention and 29.1% of variance in PA, indicating large effect sizes: $f^2_{Intention}$ = .44, f^2_{PA} = .41.

The same structural model was analyzed for the control group and the intervention group separately. The analysis for the control group yielded an acceptable model fit and the analysis for the intervention group showed a good model fit. In both analyses the same significant mediation effect was found (results not shown).[1]

Table 3.1 Maximum likelihood estimated bivariate correlations for total sample

		M	*SD*	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
1.	Physical activity t0	4.14	2.22	-									
2.	Pros t0	1.01	.53	.24***	-								
3.	Cons t0	-.99	.58	-.21***	-.29***	-							
4.	Social support t0	-.43	1.56	-.04†	.08**	.07**	-						
5.	Exercise partner t0	.62	.49	.12***	.21***	-.12***	.14***	-					
6.	Social modeling t0	.22	1.14	.06*	.04†	-.04†	.31***	.09***	-				
7.	Self-efficacy t0	.55	.69	.46***	.44***	-.37***	-.03	.15***	.09***	-			
8.	Intention t1	7.74	1.56	.38***	.44***	-.32***	-.04	.18***	.06**	.45***	-		
9.	Habit t2	.42	.72	.38***	.38***	-.20***	-.03	.18***	.05*	.46***	.46***	-	
10.	Physical activity t3	4.51	2.04	.44***	.25***	-.19***	-.02	.10***	.05*	.42***	.35***	.39***	-

Note. $N = 1976$; t0 = baseline, t1 = 3 months measurement, t2 = six months measurement, t3 = twelve months measurement.
† $p < .10$, *$p < .05$, **$p < .01$, $p < .001$*** (two-tailed).

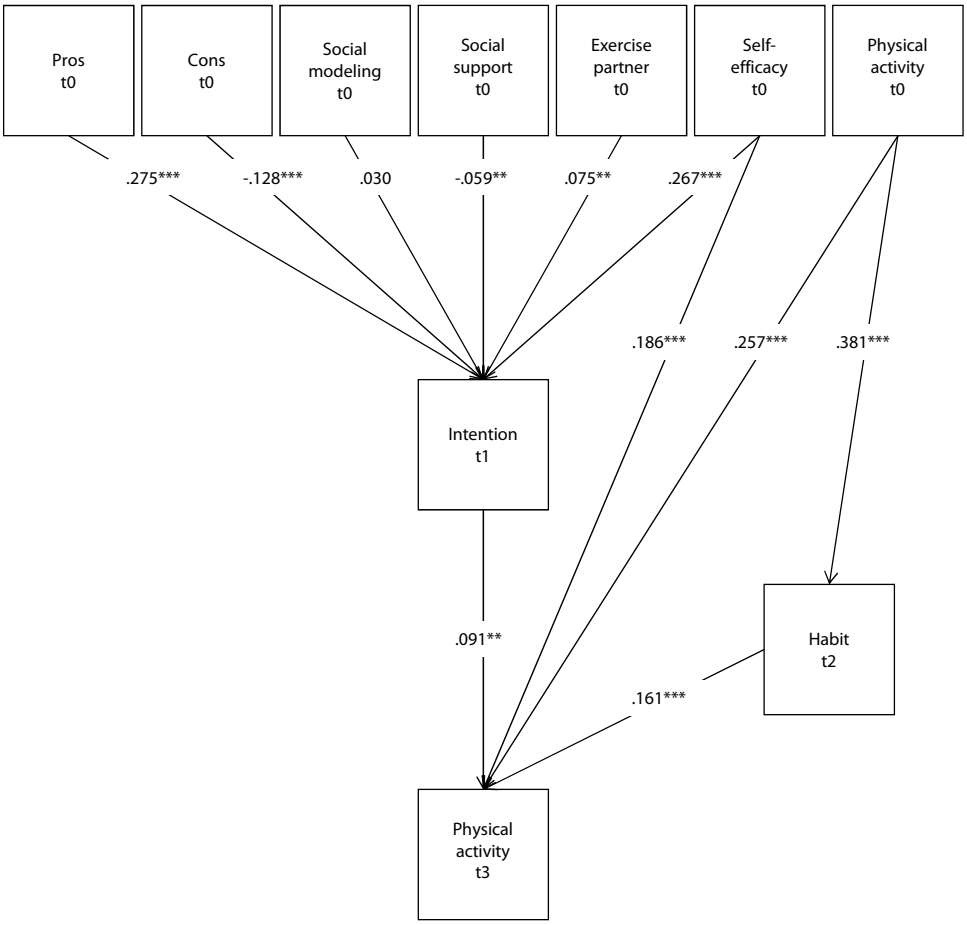

Figure 3.1 Habit as mediator of the relationship between prior and later behavior within the TPB/ASE framework

Note. Values indicate standardized maximum likelihood path estimates. The analysis was adjusted for treatment condition by the use of dummy variables. For reasons of clarity, dummy variables that control for intervention condition are not shown. The dummy variable for control condition vs. intervention basic was significant on habit(t2) and PA(t3); the dummy variable for control condition vs. intervention plus was significant on PA(t3). Model fit: χ^2 (5) = 17.78, p = .003, CFI = .99, TLI = .94, RMSEA = .04

t0 = baseline measurement, t1 = three months measurement, t2 = six months measurement, t3 = twelve months measurement.

*p < .05, **p < .01, ***p < .001 (one-tailed).

DISCUSSION

The residual variance problem refers to the question why prior behavior is a good predictor of later behavior even after TPB/ASE variables have been taken into account (Ajzen, 2002). With the aim of finding a solution to this problem, the present study tested whether habit mediates the relationship between prior and later PA in older adults. Results confirmed the hypothesized mediation.

Ajzen (2002) has set two conditions that must be met in order to accept habit as a valid explanation of the residual variance problem. First, habit must be measured with a theory-based instrument that does not solely equate habit with past behavioral frequency. By the use of the SRHI this condition is met. The SRHI namely measures, besides self-identity and automaticity, the existence of a history of repetition (Verplanken & Orbell, 2003), regardless of the number of repetitions (i.e. frequency). Thus, the SRHI does not equate habit with past behavioral frequency. Second, habit must mediate the relationship between prior and later behavior. Although not all prior PA's effect on later PA was exerted through habit (i.e. 19.3%), the results indicate that habit offers a partial solution to the residual variance problem, with small to medium effect sizes. It is not uncommon for mediation effects to be small to medium in size (MacKinnon, 2008). Moreover, we used a longitudinal design that spanned a year. Correlations tend to decrease when the temporal distance between measurement points increases (McEachan et al., 2011; Sutton, 1994), which could have affected the magnitude of the mediation effects.

The results of the present study show that habit is a relevant additional variable to the TPB/ASE model; therefore, it is recommended to incorporate habit into the TPB/ASE model. This recommendation is in line with the assumptions of dual-process theories that behavior is the result of explicit cognitions (i.e. intentions) and implicit processes (i.e. habits) (e.g. Kremers et al., 2006), as well as with the recommendation from several studies examining the moderating role of habit in the intention-PA relationship within a TPB/ASE context (e.g. Gardner, De Bruijn, & Lally, 2011; Van Bree et al., 2013).

The recommendation to incorporate habit into the TPB/ASE model implies that habit should be taken into account when developing PA interventions based on this model. In their review, Lally and Gardner (2013) identify several effective intervention strategies to target existing habits or to create new ones, such as the use of reminders, self-monitoring and self-control, awareness of cues, implementation intentions and mental contrasting. It is not always possible to include all these strategies in a single

intervention. Nonetheless, when designing health promotion interventions, such as PA interventions in older adults, for whom PA has many health benefits, it is recommended to include strategies to develop or strengthen healthy habits.

Three directions for future research emerge from the current study. First, the present study is, to our knowledge, the first study targeting the residual variance problem in the field of PA, and the second study addressing this problem using the SRHI. As the most firm conclusions need to be based on a large body of research, more studies on the mediating role of habit in the relationship between prior and later behavior are recommended, for PA as well as for other health-related behaviors. Second, habit only proved to be a partial solution to the residual variance problem in the present study, thus leaving room for further improvement. Prior PA predicts later PA both directly and via habit. One presumable source for the direct influence is shared method variance, although residual effects are not solely attributable to shared method variance (Bamberg et al., 2003; Conner et al., 1999; Verplanken, 2006). Another source could be the existence of other mediators not accounted for in this study. Several such other mediators have been proposed (see Ajzen, 2002), of which self-identity and anticipated regret are the most frequently suggested ones (Fishbein & Ajzen, 2010). However, to our knowledge, it has never been tested whether these constructs mediate the relationship between prior and later behavior. It must be noted that one of the items of the SRHI refers to self-identity[2]. It is recommended to conduct mediation analyses using self-identity and anticipated regret as mediators of the relationship between prior and later behavior in order to gain a more complete understanding of why prior behavior is such a good predictor of later behavior. Third, the present study shows that habit mediates the relationship between prior PA and later PA. Prior PA thus affects habit. In a comparable line of reasoning one could also hypothesize that later PA, which is affected by habit at an earlier time point, in turn affects habit at an even later time point. This would imply that PA mediates the relationship between prior and later habit. Both mediation hypotheses (i.e. habit mediating the relationship between prior and later PA and PA mediating the relationship between prior and later habit) could be tested simultaneously using a cross-lagged panel design. This test would contribute to further unraveling the longitudinal relationship between habit and PA. This avenue for further research is recommended for both PA and other health-related behaviors.

Some limitations of the present study have to be addressed. First, a self-report single-item measure of PA was used. Although studies provided support for the reliability and validity of single-item self-reports of PA (e.g. Milton et al., 2011), self-reports may be both higher and lower than true levels of PA (Prince et al., 2008), as they may suffer from memory biases (Scollon, Kim-Prieto, & Diener, 2003; Smyth & Stone, 2003). In order to

overcome this limitation, the use of accelerometers in future studies is recommended, as they provide objective data. Second, habit was also assessed using a self-report measure (i.e. SRHI). Although this measurement instrument is reliable and valid (Verplanken & Orbell, 2003), its nature remains subjective. Third, path analysis models have many strengths, but are not free of limitations (Lleras, 2005). The most ponderous limitation is that path analysis models treat variables as error-free representations of constructs, which can result in biased parameter estimates and in biased conclusions (Bollen, 1989; Wang & Wang, 2012). Thus, if measurement error was taken into account the magnitude of the mediation effects could have stayed nearly the same, but could also have decreased or increased. It is difficult to predict which of these consequences might follow (Bollen, 1989). Fourth, based on temporal precedence causal associations in the mediation model are assumed. However, this assumption is not a test of causal inference. Fifth, our data stem from an intervention study in which the initial response rate was not very high (i.e. 23%) and dropout was selective (for details and discussion see Van Stralen et al., 2009b, 2011). Although we corrected for possible intervention effects, this issue may affect the generalization of the results.

Several strengths of this study also have to be acknowledged. First, our study was the first to test habit's mediating role in the residual variance problem in the field of PA, applying a longitudinal design that spanned one year. Second, our research population consisted of older adults. Demographic development predictions for the near future indicate rapid aging in the western world (Christensen, Doblhammer, Rau, & Vaupel, 2009), which points out the major relevance of stimulating PA in older adults. Insight into the working mechanisms of PA may help to design interventions to increase PA in older adults. Third, as mentioned above, path analysis models have strengths (Lleras, 2005). One such strength is that, compared to regression analyses, which are frequently used in mediation studies, path analyses provide important additional information about model fit, and thus give a more complete statistical underpinning of the results. Fourth, we used the product of coefficients test, which provides a direct estimate of the mediation effect (Hayes, 2013; MacKinnon, 2008).

In sum, the present longitudinal study was the first to show that habit is a partial solution to the residual variance problem in the field of PA in older adults, indicating that habit is a relevant additional variable to the TPB/ASE model.

NOTES

[1] In the SRHI, repetition, automaticity, and expression of one's self-identity are considered core elements of habit (Verplanken & Orbell, 2003). There is, however, ongoing debate about the central characteristic of habit (e.g. Sniehotta & Presseau, 2012), with Gardner (2012) advocating that automaticity, and not repetition, is habit's core element. Based on this theorizing the Self-Report Behavioral Automaticity Index (SRBAI; Gardner, Abraham, Lally, & De Bruin, 2012b) was suggested as an alternative to the SRHI. The SRBAI consists of four automaticity items from the SRHI.

In the present study the hypothesized mediation effect was also tested using the SRBAI, yielding similar, but somewhat weaker results. Model fit: χ^2 (5) = 16.55, p = .005, CFI = .99, TLI = .93, RMSEA = .03. Significant mediation effect: z = 3.26, p = .001, CI = [.01; .04], $\hat{a}\hat{b}_{cs}$ = .03, PME = 8.5%.

The same path model was analyzed for the control group and the intervention group separately. The control group analysis yielded an acceptable model fit. The intervention group analysis showed a good model fit. The same significant mediation effect was found in both analyses (results not shown).

[2] The self-identity item of the SRHI is, as well as seven other items, no part of the SRBAI (see Note 1). The mediation effect of the SRBAI in the present study was smaller than the mediation effect of the SRHI, possibly partly due to the item referring to self-identity.

CHAPTER 4

MODELING LONGITUDINAL RELATIONSHIPS BETWEEN HABIT AND PHYSICAL ACTIVITY: TWO CROSS-LAGGED PANEL DESIGN STUDIES IN OLDER ADULTS

Rob J.H. van Bree
Catherine Bolman
Aart N. Mudde
Maartje M. van Stralen
Denise A. Peels
Hein de Vries
Lilian Lechner

Journal of Aging and Physical Activity, 2017, 25, 464-473. doi: 10.1123/japa.2016-0212

ABSTRACT

Objectives: These longitudinal studies examined whether habit mediates the relationship between prior and later PA and whether PA simultaneously mediates the relationship between prior and later habit.

Methods: Two independent studies were conducted among 1976 (Study 1: M_{age} = 63.63, *SD* = 8.66) and 2140 (Study 2: M_{age} = 62.75, *SD* = 8.57) adults aged 50 years or older. Data on habit and PA were collected by means of questionnaires at baseline (t0) and at six (t1) and twelve (t2) months after baseline measurement. Cross-lagged panel designs were used.

Results: Results of structural equation modeling analyses were not unambiguous. Indications for the existence of both hypothesized mediation effects were found, but no clear, unequivocal pattern appeared.

Conclusions: Somewhat more support was found for the PA-habit-PA path than for the habit-PA-habit path. More research is needed to draw more definitive conclusions.

INTRODUCTION

Regular physical activity (PA) is associated with many physical and mental health benefits (e.g. Hamer, Lavoie, & Bacon, 2014; Lee et al., 2012; Reiner, Niermann, Jekauc, & Woll, 2013). Worldwide, a large proportion of older adults are currently insufficiently active to obtain these health benefits (Hallal et al., 2012; Sun, Norman, & While, 2013). In the Netherlands, where the current studies were conducted, 40% of the adults aged 45 to 65 and 31% of the adults aged 65 and older, are insufficiently physically active (Centraal Bureau voor de Statistiek, 2016). They do not meet the international PA recommendation to be at least moderately physically active for at least 30 minutes per day on at least five days per week (Haskell et al., 2007; Nelson et al., 2007). Consequently, stimulating PA in this age group by developing effective PA interventions is of major relevance. Development of such effective interventions relies on insight into the determinants of PA and their working mechanisms. In order to contribute to this insight, the current studies examine whether habit mediates the relationship between prior and later PA and whether PA simultaneously mediates the relationship between prior and later habit (see Figure 4.1 for conceptual model).

Many health behaviors are typically executed repeatedly (Ajzen, 2002; Verplanken, 2010). Repetition may result in habit formation. That is, habits form through satisfactorily repeating behavior in a specific context (Lally, Van Jaarsveld, Potts, & Wardle, 2010), whereby control over the behavior is gradually transferred from deliberative thoughts to contextual stimuli (Lally, Wardle, & Gardner, 2011). As a result these contextual stimuli acquire the potential to activate behavior, so that upon encountering these stimuli, automatic, habitual responses are activated (Bargh, 1994; Orbell & Verplanken, 2010). These responses are performed in the absence of conscious control or mental effort (Verplanken, 2006; Wood, Quinn, & Kashy, 2002). Automatic, habitual behavior does not depend on supporting intentions and should thus persist even when motivation or self-control resources are lowered (Gardner, 2015; Neal, Wood, & Drolet, 2013). Drawing on this feature, calls have been made to encourage habit formation in interventions in order to promote long-term maintenance of health behavior (Rothman, Sheeran, & Wood, 2009).

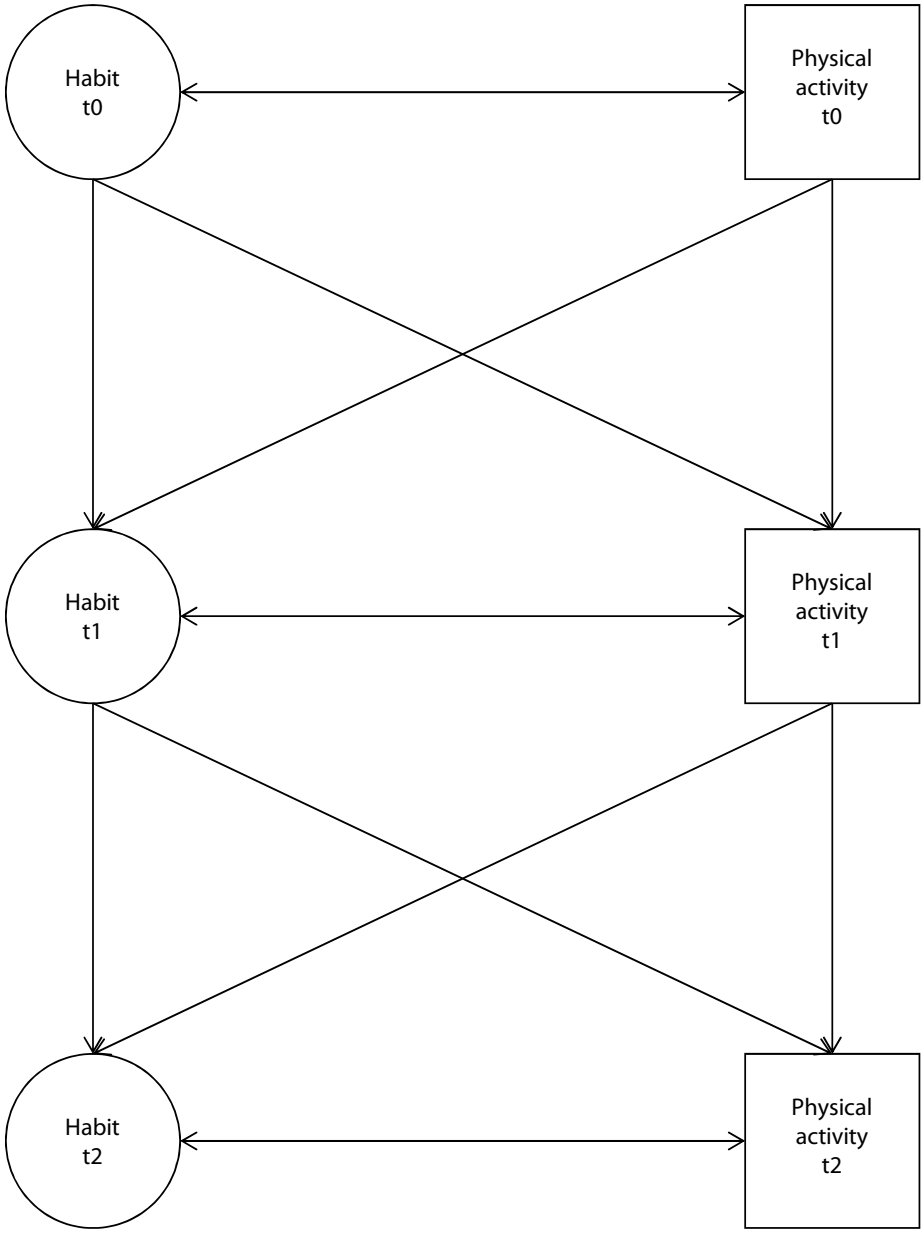

Figure 4.1 Conceptual model for the relationships between PA and habit

Note: Age and the presence of a functional limitation were used as covariates. For reasons of clarity, dummy variables and covariates are not shown.
Latent variables are represented in circles, observed variables in rectangles.
t0 = baseline measurement, t1 = six months measurement, t2 = twelve months measurement.

Like many health behaviors, such as alcohol consumption (Norman, 2011), fruit consumption (De Bruijn, 2010; De Bruijn, Keer, Conner, & Rhodes, 2012; Guillaumie, Godin, & Vézina-Im, 2010), and adherence to asthma medication (Bolman, Arwert, & Völlink, 2011), PA has a habitual component, which has been found to be noticeable in at least four different ways. First, PA correlates moderately to strongly with habit (Gardner, De Bruijn, & Lally, 2011). Second, habit typically explains additional variance in PA over and above intentions (e.g. Rhodes & De Bruijn, 2010). Third, habit moderates the influence of intention on light or moderate PA; intention becomes less predictive of PA as habit strength increases (e.g. Gardner et al., 2011; Van Bree et al., 2013). Fourth, within the framework of the theory of planned behavior (Ajzen, 1991), habit mediates the relationship between prior and later PA, as was shown in a recent study (Van Bree et al., 2015). Habit thus provides a psychological mechanism that partly explains why prior PA is such a good predictor of later PA. However, the longitudinal relationship between habit and behavior still leaves questions open and need to be unraveled in more depth. Habit theory states that performing behavior as a partly or completely automatically activated, habitual response to contextual stimuli strengthens existing habits until habit strength asymptotically reaches a plateau (Lally et al., 2010). This process of habit formation applies to both experimental and nonexperimental (i.e. natural) settings. Thus, whereas the study by Van Bree et al. (2015) found that prior PA affects habit, which in turn affects later PA, it could also be hypothesized that later PA, which is affected by habit at an earlier time point, in turn affects habit at an even later time point. This would imply that PA mediates the relationship between prior and later habit. We are not aware of any study testing this hypothesis. Both mediation hypotheses (i.e. PA-habit-PA and habit-PA-habit) can be tested simultaneously using a cross-lagged panel design (see Figure 4.1). The time frames in such a design are the same for both mediation effects. Although the hypotheses have a strong common sense character, systematically testing them to sort out whether they can be confirmed or not, contributes valuably to a solid theoretical foundation of the interplay between habit and PA. Moreover, insight into these mediation effects in experimental and nonexperimental settings is important for intervention development as well. Meta-analyses found that long-term gains of PA interventions are often limited (Antikainen & Ellis, 2011; Feldsjoe, Neuhaus, Winkler, & Eakin, 2011). Habit formation is a desired outcome for many PA interventions (Lally & Gardner, 2013) as it contributes to maintenance (Rothman et al., 2009). However, although their implicit goal often is that a newly acquired behavioral pattern becomes habitual, the majority of intervention studies are not grounded in habit formation theory (Lally, Chipperfield, & Wardle, 2008). Understanding the relationships between PA and habit may be helpful when designing PA interventions focused on habit

formation. A significant PA-habit-PA path would support the implicit assumption that PA sustains over time through habit. A strong habit-PA-habit path would indicate that PA interventions could benefit from incorporating explicit habit formation strategies.

The current studies target adults aged 50 years or older, which is a growing population in the western world (Christensen, Doblhammer, Rau, & Vaupel, 2009). The purpose of the current studies is to perform structural equation modeling (SEM) analyses to examine, in a cross-lagged panel design, whether habit mediates the relationship between prior and later PA and whether PA mediates the relationship between prior and later habit. It is hypothesized that both mediation effects occur simultaneously.

METHODS

Data of two independent studies were used. The Medical Ethics Committee of Maastricht University and the University Hospital Maastricht approved the study protocol of Study 1. That study was registered at the Dutch Trial Register (NTR920). Study 2 was approved by the Medical Ethics Committee of Atrium-Orbis-Zuyd and registered at the Dutch Trial Register (NTR2297). For both studies informed consent was obtained from all participants.

Participants and procedures

Study 1. This study was a secondary analysis of data from a clustered randomized controlled trial (RCT) testing the efficacy of two tailored interventions aimed at promoting PA and long-term maintenance of PA in adults, aged 50 years or older (see Van Stralen, De Vries, Mudde, Bolman, & Lechner, 2009b, 2011). A wait list control condition was part of the RCT. At the end of the study, participants from the control condition were given access to the intervention content. Data from both the control group and the two intervention conditions were used in the current study. The procedure of the RCT, including the selection, enrollment, and dropout of participants, the distribution and content of the questionnaires, and the interventions are described in detail elsewhere (see Van Stralen et al., 2008, 2011).

Via six randomly selected Municipal Health Councils, 8500 Dutch adults, aged 50 years or older, were invited by a written letter to participate in the study. A total of 1976 adults (23%) agreed to participate and completed the baseline questionnaire. Of these participants, 30% were assigned to the control condition and 70% to the two intervention conditions. Retention rates at three, six, and twelve months were 74%, 71%, and 68% respectively, in contrast to the number of baseline participants.

Study 2. This study was a secondary analysis of data from a RCT that aimed to compare the effectiveness and cost-effectiveness of four tailored PA interventions for adults aged 50 years or older (for long-term effectiveness studies see Peels et al., 2013; for long-term cost-effectiveness studies see Peels et al., 2014). At the end of the study, control group participants were given access to the intervention content. In the current study data from both the control group and the four intervention conditions were used. The procedure of the RCT, including the selection, the participation, and dropout rates, the delivery mode and content of the questionnaires, and the interventions are described in detail elsewhere (see Peels et al., 2013).

In six Municipal Health Council regions, 13666 Dutch adults, aged 50 years or older, were invited by a written letter to participate in the study. A total of 2140 adults (16%) agreed to participate and completed the baseline questionnaire. Of these participants, 19% were assigned to the control condition and 81% to the four different intervention conditions. In contrast to the number of baseline participants, retention rates at three, six, and twelve months were 58%, 55%, and 59% respectively.

Measures

Study 1. Data were collected by means of extensive questionnaires at baseline and at three, six, and twelve months after baseline measurement (see Van Stralen et al. 2008, 2011 for details). For the current study, data on PA and habit from the baseline (t0), six months (t1), and twelve months (t2) measurement were used. Baseline measurement lasted from March to June.

At baseline, *age*, *gender, body mass index (BMI)*, *educational level* (low, medium, or high), *marital status* (having a partner or not having a partner), and the presence of a *functional limitation* were assessed.

Items referred to sufficient PA, which, in accordance with the PA recommendation for people aged 50 years or older (Haskell et al., 2007; Nelson et al., 2007), was explicitly defined as being at least moderately physically active for at least 30 minutes per day on at least five days per week. This definition was repeated several times as a reminder. These reminders were spread proportionally over the questionnaire. Whereas participants were instructed to report their PA of an average, normal week in the last month, the items measuring habit did not refer to a specific time frame.

The primary outcome measure was *total weekly days of PA*, assessed with the self-administered Dutch short questionnaire to assess health-enhancing PA (SQUASH). The overall reliability ($r_{spearman}$ = .57) and relative validity of the SQUASH in relation

to Actigraph™ activity monitors ($r_{spearman}$ = .67) were reasonable in older subjects (Wagenmakers et al., 2008). A single-item question of the SQUASH was used: 'On how many days per week are you, in total, at least moderately physically active for at least 30 minutes by undertaking, for example, heavy walking, cycling, chores, gardening, sports or other moderate or vigorous physical activities?' Although single-item self-reports may be less accurate, studies provided support for the validity and reliability of single-item self-reports of PA (Iwai et al., 2001; Jackson, Morrow, Bowles, FitzGerald, & Blair, 2007; Li, Carlson, & Holm, 2000; Milton, Bull, & Bauman, 2011; Milton, Clemes, & Bull, 2013; Wanner et al., 2014; Weiss et al., 1990). The percentage of occasional missing values (i.e. not due to dropout) for PA was 0.4% (t0), 0.1% (t1), and 0.1% (t2).

Habit was measured using the Self-Report Behavioral Automaticity Index (SRBAI; Gardner, Abraham, Lally, & De Bruijn, 2012b). The SRBAI consists of four items: 'Being sufficiently physically active is something …I do automatically, …I do without having to consciously remember, …I do without thinking, …I start doing before I realize I'm doing it'. Answering options ranged from 'totally disagree' (-2) to 'totally agree' (2). Cronbach's alpha was .88 (t0), .86 (t1), and .86 (t2). The average percentage of occasional missing values for habit items was 6.5% (t0), 5.3% (t1), and 2.7% (t2).

Study 2. Similar to the approach in Study 1, data were collected by means of questionnaires at baseline and at three, six, and twelve months after baseline measurement (see Peels et al., 2012 for details). Data on demographic (t0) and health-related (t0) characteristics and on PA and habit from the baseline (t0), six months (t1), and twelve months (t2) measurement were used in this study. Baseline measurement lasted from November to March.

The definition of sufficient PA and the operationalization of *total weekly days of PA* are the same as in Study 1. The percentage of occasional missing values for PA was 2.2% (t0), 3.6% (t1), and 2.2% (t2). *Habit* was measured in a slightly different way compared to Study 1. In Study 2 four automaticity items were taken from the Self-Report Habit Index (SRHI; Verplanken & Orbell, 2003). Two of these items are also part of the SRBAI (see Study 1), the other two are not. Participants had to rate four statements: 'Being sufficiently physically active is something …I do automatically, …I start doing before I realize I'm doing it …I would find hard not to do, …I have no need to think about doing'. Answering options ranged from 'totally disagree' (-2) to 'totally agree' (2). Cronbach's alpha was .90 (t0), .87 (t1), and .86 (t2). The average percentage of occasional missing values for habit items was 2.7% (t0), 5.7% (t1), and 4.7% (t2).

Analyses

Means and standard deviations were calculated using SPSS 23. The research questions were examined in a SEM framework. The analyses were conducted with Mplus 5.21 (Muthén & Muthén, 1998-2007), using maximum likelihood estimation to cope with missing values.

Participants of both the control group and the intervention conditions were included in the current studies. To control for influence of interventions, the analyses were adjusted for treatment condition by the use of dummy variables. However, in order to eliminate any concern about possible residual intervention effects not controlled for by dummy variables, the analyses were also conducted in the control group alone.

As recommended by Byrne (2012), the measurement model and structural model were constructed separately. Habit was a latent construct, measured by separate indicators, as defined in the description of the questionnaire. Confirmatory factor analysis was used to test the measurement model. A minimum factor loading of .40 was applied (Stevens, 2002). The adequately defined measurement model was used for the path analysis with latent variables in the structural model.

In the structural model t0 variables were modeled as predictors of t1 variables, which, in turn, were modeled as predictors of t2 variables. Age and the presence of a functional limitation were included as covariates for t1 and t2 variables. In addition to the structural paths, covariances between predictor variables at each time point were included (see Figure 4.1). Furthermore, since panel data were used, identical indicators across time points were expected to correlate (Bollen, 1989; Landis, Edwards, & Cortina, 2009). Therefore, residual covariances among all identical indicators were defined a priori.

Overall model fit was assessed using a combination of fit indices. Chi-square tests were conducted to test for differences between theoretical and observed models. A good model fit is indicated by $p > .05$ (Tabachnick & Fidell, 2007). This *p*-value, however, is sensitive to large sample sizes and easily produces a statistically significant result therein (Kline, 2011). In addition, Root Mean Square Error of Approximation (RMSEA), Comparative Fit Index (CFI), and Tucker-Lewis Index (TLI) were calculated to evaluate model fit. An adequate model fit is indicated by RMSEA < .08, CFI > .90, and TLI > .90 (Schumacker & Lomax, 2010; Van de Schoot, Lugtig, & Hox, 2012), whereas a good model fit is obtained when RMSEA < .06, CFI > .95, and TLI > .95 (Hu & Bentler, 1999).

Mediation effects were estimated using the product of coefficients test (e.g. MacKinnon, 2008). This test determines how much of the effect of an independent variable on a dependent variable is exerted through one or more mediator variables. It assumes the mediation effects to be normally distributed, which is usually only the case in large samples (Jose, 2013), a prerequisite that is met in this study. In addition, 95% confidence intervals (CI) based on the distribution of the product were calculated, using RMediation (Tofighi & MacKinnon, 2011). CI's based on the distribution of the product take nonnormality of the mediation effects into account (Tofighi & MacKinnon, 2011). The percentage mediated effect (PME) was used as an effect size to evaluate the magnitude of the mediation effects (see MacKinnon, 2008). PME requires a sample size of at least 500 (MacKinnon, Warsi, & Dwyer, 1995), a criterion that is met in this study. The completely standardized indirect effect ($\hat{a}\hat{b}_{cs}$; Preacher & Kelley, 2011) was also used as an effect size. This effect size was evaluated according to Cohen's r^2 criteria (.01 = small; .09 = medium; .25 = large; Cohen, 1988). The total amount of variance explained in PA(t1), PA(t2), habit(t1), and habit(t2) was calculated and evaluated using Cohen's f^2 effect size (.02 = small; .15 = medium; .35 = large; Cohen, 1988).

RESULTS

Descriptives

Study 1. With participants' ages varying from 50 to 98 years, the mean age in the total sample was 63.63 years (*SD* = 8.66). Males were slightly underrepresented (43%). About half of the participants (51%) met the PA recommendation at baseline. Functional limitations were reported by 30% of participants. The average BMI was 25.48 (*SD* = 3.76). Level of education was low for 48%, medium for 19%, and high for 33% of participants. Of all participants, 81% had a partner. Means and standard deviations of PA and habit and maximum likelihood bivariate correlations are shown in Table 4.1.

Study 2. Participants' ages varied from 49 to 94 years (*M* = 62.75, *SD* = 8.57). Sex was nearly equally distributed (51% women, 49% men). Less than half of the participants (44%) met the PA recommendation at baseline. Functional limitations were reported by 45% of participants. The average BMI was 25.86 (*SD* = 3.99). Of all participants, level of education was low for 47%, medium for 27%, and high for 26%, while 83% reported having a partner. Descriptive statistics of PA and habit are provided in Table 4.1.

Table 4.1 Means, standard deviations, ranges, and maximum likelihood estimated bivariate correlations for Study 1 and Study 2

Study 1										
		M	***SD***	**Range**	**1.**	**2.**	**3.**	**4.**	**5.**	**6.**
1.	Physical activity t0	4.14	2.22	0 - 7	-					
2.	Physical activity t1	4.61	1.98	0 - 7	.47	-				
3.	Physical activity t2	4.55	2.02	0 - 7	.44	.56	-			
4.	Habit t0	.41	.86	-2 - 2	.34	.27	.27	-		
5.	Habit t1	.38	.82	-2 - 2	.27	.32	.26	.63	-	
6.	Habit t2	.37	.85	-2 - 2	.29	.31	.33	.63	.66	-
Study 2										
		M	***SD***	**Range**	**1.**	**2.**	**3.**	**4.**	**5.**	**6.**
1.	Physical activity t0	4.02	2.03	0 - 7	-					
2.	Physical activity t1	4.85	1.84	0 - 7	.56	-				
3.	Physical activity t2	4.49	1.98	0 - 7	.53	.61	-			
4.	Habit t0	.45	.89	-2 - 2	.50	.44	.38	-		
5.	Habit t1	.45	.83	-2 - 2	.49	.51	.44	.71	-	
6.	Habit t2	.45	.81	-2 - 2	.43	.44	.47	.67	.77	-

Note. All correlations stem from model estimations in which only the correlations depicted above and residual covariances between identical indicators across time points were defined. For Study 1 (N = 1976) that model yielded a good model fit: χ^2 (66) = 443.29, p < .001, CFI = .97, TLI = .95, RMSEA = .05. For Study 2 (N = 2140) the model showed a good model fit: χ^2 (66) = 308.92, p < .001, CFI = .98, TLI = .97, RMSEA = .04.
t0 = baseline measurement, t1 = six months measurement, t2 = twelve months measurement.
All correlations are significant at .001 level (two-tailed).

Measurement models

Study 1. The measurement model showed a good model fit, χ^2 (39) = 195.78, $p < .001$, CFI = .98, TLI = .97, RMSEA = .05. With factor loadings ranging from .70 to .85, all factor loadings exceeded the minimum level of .40.

Study 2. The measurement model yielded a good model fit, χ^2 (39) = 252.28, $p < .001$, CFI = .98, TLI = .97, RMSEA = .05, with factor loading ranging from .74 to .89.

Structural models

Study 1. The structural regression model yielded an acceptable model fit, χ^2 (106) = 652.03, $p < .001$, CFI = .95, TLI = .93, RMSEA = .05. A significant mediation effect was found for the habit(t0)-PA(t1)-habit(t2) path (product of coefficients' $z = 2.73$, $p = .006$, CI = [.004; .019], $\hat{a}\hat{b}_{cs} = .011$, PME = 2.7%). The PA(t0)-habit(t1)-PA(t2) path reached marginal significance ($z = 1.84$ $p = .067$, CI = [.000; .011], $\hat{a}\hat{b}_{cs} = .005$, PME = 2.4%) (see Figure 4.2). The $\hat{a}\hat{b}_{cs}$'s of the significant mediation effects indicate small effect sizes. Age(t0) was not a significant predictor of PA and habit on both t1 and t2 ($p > .10$). Less functional limitations on baseline predicted more PA (path estimate = .072, $p = .004$) and habit (path estimate = .093, $p < .001$) on t2, but not on t1 ($p > .10$).

The structural model explained 25.2% of variance in PA(t1), 33.5% of variance in PA(t2), 44.7% of variance in habit(t1), and 49.1% of variance in habit(t2), indicating large effect sizes: $f^2_{PA(t1)} = .34$, $f^2_{PA(t2)} = .50$, $f^2_{Habit(t1)} = .81$, and $f^2_{Habit(t2)} = .96$.

The same structural model was analyzed using only control group data. The analysis showed an acceptable model fit. The habit(t0)-PA(t1)-habit(t2) path was significant, whereas the PA(t0)-habit(t1)-PA(t2) path was not[1].

Study 2. The model fit for the structural regression model was good, χ^2 (124) = 472.86, $p < .001$, CFI = .97, TLI = .96, RMSEA = .04. A significant mediation effect was found for the path PA(t0)-habit(t1)-PA(t2) ($z = 4.07$, $p < .001$, CI = [.016; .044], $\hat{a}\hat{b}_{cs} = .030$, PME = 10.8%). The $\hat{a}\hat{b}_{cs}$ indicates a small effect size. The mediation effect of the habit(t0)-PA(t1)-habit(t2) path was not significant ($z = 1.22$, $p = .221$, CI = [-.004; .017], $\hat{a}\hat{b}_{cs} = .007$, PME = 1.3%) (see Figure 4.2). Age(t0) did not predict PA on both t1 and t2 ($p > .10$) and had marginally significant relationships with habit on t1 (path estimate = -.040, $p = .092$) and t2 (path estimate =.045, $p = .059$). Less functional limitations on baseline predicted more PA (path estimate = .068, $p = .004$) and habit (path estimate = .055, $p = .022$) on t2, but not on t1 ($p > .10$).

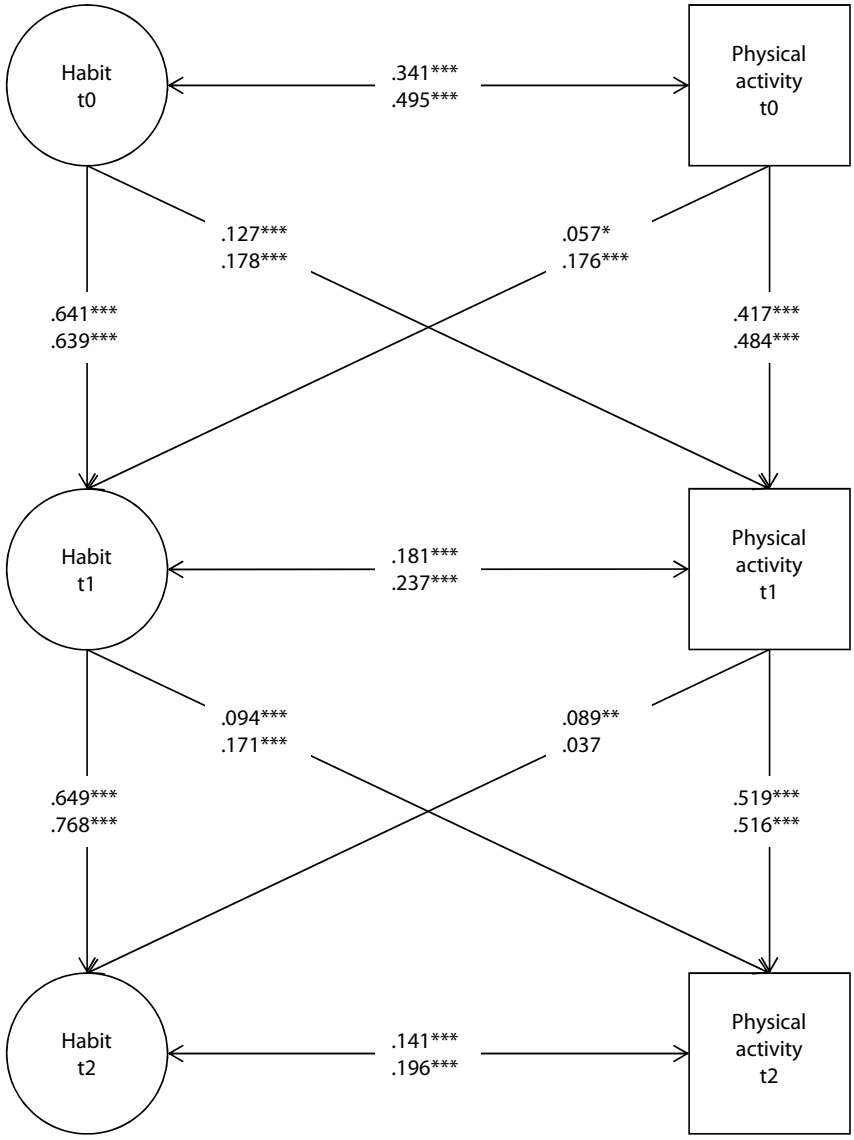

Figure 4.2 Cross-lagged panel design with three-wave data

Note. Top values indicate standardized maximum likelihood estimates for Study 1; bottom values indicate standardized maximum likelihood estimates for Study 2. Results for analyses using data from both control and intervention conditions are shown. The analyses were adjusted for treatment condition by the use of dummy variables. Age and the presence of a functional limitation were used as covariates. For reasons of clarity, dummy variables and covariates are not shown. Latent variables are represented in circles, observed variables in rectangles. Model fit for Study 1: χ^2 (106) = 652.03, $p < .001$, CFI = .95, TLI = .93, RMSEA = .05. Model fit for Study 2: χ^2 (124) = 472.86, $p < .001$, CFI = .97, TLI = .96, RMSEA = .04.
t0 = baseline measurement, t1 = six months measurement, t2 = twelve months measurement.
*$p < .05$, **$p < .01$, ***$p < .001$ (two-tailed).

The structural model explained 37.9% of variance in PA(t1), 41.3% of variance in PA(t2), 57.0% of variance in habit(t1), and 64.1% of variance in habit(t2), indicating large effect sizes: $f^2_{PA(t1)} = .61$, $f^2_{PA(t2)} = .70$, $f^2_{Habit(t1)} = 1.33$, and $f^2_{Habit(t2)} = 1.79$.

The analysis was also conducted using only control group data. The model fit was found to be acceptable. The PA(t0)-habit(t1)-PA(t2) path was significant. The habit(t0)-PA(t1)-habit(t2) path was not significant[2].

DISCUSSION

The two current longitudinal studies in older adults used a cross-lagged panel design to test the hypothesis that habit mediates the relationship between prior and later PA, while PA simultaneously mediates the relationship between prior and later habit. Results were to some degree ambiguous (see Table 4.2). The hypothesized mediating role of PA in the relationship between prior and later habit was confirmed in Study 1. However, this result was not replicated in Study 2. The PA-habit-PA path was marginally significant in Study 1 and significant in Study 2 when using data for analysis from the combined control and intervention conditions. This path also reached significance when only using control group data in Study 2, but not in Study 1. The effect sizes of all significant mediation effects were small. It is, however, not uncommon for mediation effects to be small in size (MacKinnon, 2008). Altogether, the current studies found indications for the existence of both hypothesized mediation effects. These indications were somewhat stronger for the PA-habit-PA path than for the habit-PA-habit path (see Table 4.2). Overall, results did not show a clear, unequivocal pattern.

Table 4.2 Significances and nonsignificances of mediation effects for Study 1 and Study 2

		habit(t0)-PA(t1)-habit(t2)	PA(t0)-habit(t1)-PA(t2)
Study 1	Intervention and control group	Significant	Marginally significant
	Control group	Significant	Nonsignificant
Study 2	Intervention and control group	Nonsignificant	Significant
	Control group	Nonsignificant	Significant

Evidence, albeit not unequivocal, was found for the PA-habit-PA path. This result strengthens an assumption underlying many interventions. PA interventions in older adults often result in small and short-lived behavior changes (Van der Bij, Laurant, & Wensing, 2002). Habit formation has been proposed as an effective way to prevent

relapses and to ensure long-term maintenance of behavior (Lally et al., 2008; Rothman et al., 2009; Verplanken & Wood, 2006). Based on this proposition habit formation intervention studies have been conducted in several health domains, such as weight loss (Lally et al., 2008), dental flossing (Judah, Gardner, & Aunger, 2013), balance and strength training (Fleig et al., 2016), and exercise (Fleig, Pomp, Schwarzer, & Lippke, 2013). Quantitative analyses showed that these interventions were effective. Qualitative analyses indicated that participants experienced increases in automaticity (Fleig et al., 2016; Lally et al, 2008, 2011). These findings demonstrate that habit formation via an intervention is possible. However, the majority of intervention studies do not explicitly target habit formation, but assume that behavior will gradually become habitual (Lally et al., 2008). In other words, in the PA domain many interventions assume a PA-habit-PA path. As can be seen in Table 4.2, the current studies found significant PA-habit-PA paths in two out of four tests and a marginal significant path in one out of four tests. This result partly confirms the hypothesis of existence of PA-habit-PA paths in nonintervention settings (i.e. the analyses were either controlled for intervention condition or were only conducted in control groups) and strengthens the abovementioned assumption underlying many interventions. How can the nonsignificant finding in the analysis of the control group of Study 1 be explained? In Study 1, the control group may lack power, which was noticeable in the maximum likelihood path estimate of PA(t0) on habit(t1) of the control group compared to the estimate of the combination of control and intervention conditions. Although the estimates were roughly the same, the estimate was significant (.057, see Figure 4.2) when analysing data from the combination of control and intervention conditions, but not significant when using data from only the control group (.063, result not shown). The nonsignificance of the PA-habit-PA path in the control group may as well be ascribed to a lack of power. At the same time, this mediation effect was significant in the control group in Study 2. What could be the reason for this dissimilarity in results between Study 1 and Study 2? In Study 2 the correlation between PA(t0) and habit(t1) was stronger than in Study 1, which may account for a stronger maximum likelihood path estimate of PA(t0) on habit(t1) in Study 2 (.210, significant, result not shown) than in Study 1 (.063, not significant, result not shown). The weaker correlation has contributed as well to the nonsignificance of the mediation effect in Study 1. Different operationalizations of habit may account for the differences in correlations between Study 1 and Study 2. In Study 1 the SRBAI (Gardner et al., 2012b) was used. This measurement instrument consists of four automaticity items taken from the SRHI (Verplanken & Orbell, 2003). In their validation study Gardner et al. (2012b) found that although seven SRHI-items measured automaticity, four of them most confidently and consistently captured habit's automaticity. The SRBAI is built up of these four items. In Study 2 an alternative habit scale was used, consisting of two

SRBAI-items and two out of the three automaticity items from the SRHI that were not included in the SRBAI. Of these latter two items, not each judging expert in the study by Gardner et al. (2012b) was at least 90% certain that they represented automaticity. The habit scale that was used in Study 2 has thus captured habit's automaticity differently compared to Study 1, and with slightly less confidence. The difference in habit scales may have had an impact on the correlations with PA, resulting in stronger correlations for the alternative habit scale with PA than for the SRBAI. In sum, the current studies found indications that PA sustains over time through habit, although the pattern was not completely unequivocal. In order to gain deeper insight into habit's role as mediator of the relationship between prior and later PA, it is recommended to replicate the current studies, using observational as well as experimental designs.

The habit-PA-habit path reached significance in Study 1 when using data from the combination of control and intervention conditions as well as from the control group alone. These findings were not replicated in Study 2 (see Table 4.2). What may account for these different findings? The main difference between Study 1 and Study 2 is the path from PA(t1) leading to habit(t2). Despite a stronger correlation between PA(t1) and habit(t2) in Study 2 than in Study 1, the path from PA(t1) on habit(t2) was significant in Study 1, but not in Study 2 (see Figure 4.2). Both studies share strong autoregression from habit(t1) on habit(t2), albeit that this autoregression seems to be stronger in Study 2. The difference in autoregression may be a consequence of different operationalizations of habit as described above. The stronger autoregression in Study 2 may have left too little variance in habit(t2) to be modeled by PA(t1). In all, the findings of the current studies show an equivocal pattern that only partly supports that habit sustains over time through PA, thereby contributing to PA behavior. Based on Study 1 it is recommended to incorporate strategies into interventions for older adults that explicitly focus on forming new PA habits, that expand existing habitual PA patterns (e.g. walking 30 minutes instead of 20 minutes after every evening meal) and/or that increase the level of PA contained therein (e.g. intensive walking instead of moderate walking after every evening meal). This recommendation, however, has no foundation in Study 2. More research on the habit-PA-habit path is therefore recommended.

Whereas the mean scores on habit in the current studies were quite stable, PA scores seemed to increase from t0 to t2 (see Table 4.1). This result may indicate that a habit at the same level of strength, but for more PA was developed. From a health perspective that would be a clear gain. The stable mean habit scores were far from the maximum level of the scale (see Table 4.1). Why did habit not increase despite PA enactment? In their experiment, Lally et al. (2010) found that the plateau of habit strength that many participants reached for exercise was below the maximum score for habit. Thus,

although below the scale maximum, the rather stable mean scores on habit in the current study may indicate that the research sample had already reached its plateau of habit strength at the start of the study. Small decreases in mean habit strength may be an effect of measuring at this plateau. In order to get a more complete understanding of the mutual influence of PA and habit, it is recommended to replicate the current studies using samples that have lower mean scores on habit at baseline. In addition, another mechanism may have caused small decreases in mean habit scores. Filling in PA questionnaires may have increased the level of awareness of PA behavior, which, in turn, may have negatively affected the unaware, habitual response.

The current studies raised ambiguous findings. As stated above, replication studies are warranted, using both observational and experimental designs. In addition, another direction for future research needs to be mentioned. Examining the longitudinal mediated relationships between habit and health-related behaviors other than PA is recommended. Habits are after all not only important for PA, but also for other health-related behaviors. Research on these mediated relationships can contribute to a fuller grasp of habits. Cross-lagged panel designs may be used as well. A major advantage of cross-lagged panel designs for mediation analysis is that several mediation effects can be tested simultaneously using the same time frame. Variations in populations and in the time lags used will contribute to a deeper and more complete understanding of mediated relationships between habit and health-related behaviors.

Age did not exert a clear influence on PA and habit. The presence of a functional limitation did neither affect PA(t1) nor habit(t1). Three out of four tests showed that the absence of a functional limitation at baseline was associated with more PA one year later (i.e. at t2). While in two out of four tests a significant association was found with habit(t2), in one out of four tests a marginal significant association was found. In light of prevention these results are relevant, as the trend in results seems to indicate that once an older adult has a functional limitation, this will affect the level of PA and habit on the long run. This implies that functional limitations should be addressed, considered, and anticipated in interventions for older adults. How can this be done? Older adults often attribute functional limitations unjustly to the aging process rather than to volitionally controllable, unstable, external sources (Levy, Ashman, & Slade, 2009; Sarkisian, Liu, Ensrud, Stone, & Mangione, 2001), which implies that PA interventions should target older adults' views on aging (Wolff, Warner, Ziegelmann, & Wurm, 2014). Furthermore, many injuries and subsequent functional limitations in older adults are caused by falls (Rubenstein, 2006). PA interventions in older adults should thus include falls prevention. PA programs for older adults that include balance and strength training have been proven effective in reducing falls as well as the risk of falling (Karlsson, Vonschewelov,

Karlsson, Cöster, & Rosengen, 2013; Sherrington, Tiedemann, Fairhall, Close, & Lord, 2011). Fleig et al. (2016) showed that older adults can form balance and strength exercise habits.

When functional limitations first arise, they may signal a major life change, depending on the seriousness. Other major life changes for older adults are, for instance, entering retirement, becoming grandparents, moving houses. Major life changes often disrupt the connection between critical cues in an environment and habitual action (Verplanken & Wood, 2006; Wood, Tam, & Guerrero Witt, 2005). This opens a window in which a new habit can be attached to cues in the environment (Verplanken & Wood, 2006), which may as well be a PA habit for activities that are still possible in presence of a functional limitation. In their review, Lally and Gardner (2013) identify several effective intervention strategies to create new habits, such as the use of reminders, self-monitoring and self-control, awareness of cues, implementation intentions, and mental contrasting.

Some limitations of the present study have to be addressed. First, a self-report single-item measure of PA was used. Although studies provided support for the reliability and validity of single-item self-reports of PA (Iwai et al., 2001; Jackson et al., 2007; Li et al., 2000; Milton et al., 2011, 2013; Wanner et al., 2014; Weiss et al., 1990), self-reports may be both higher and lower than true levels of PA (Prince et al., 2008), as they may suffer from memory biases (Scollon, Kim-Prieto, & Diener, 2003; Smyth & Stone, 2003). The use of accelerometers in future studies is recommended, as they overcome problems with recall and memory bias. However, accelerometers are also not without limitations, since they cannot accurately detect PA in situations where much of the body remains stationary (e.g. cycling or arm movements in resistance training; Andre & Wolf, 2007; Bassett et al., 2000; Esliger, Copeland, Barnes, & Tremblay, 2005; Hendelman, Miller, Baggett, Debold, & Freedson, 2000). A recent study found that not all accelerometers are valid (Berendsen et al., 2014). Moreover, the utility of accelerometers is affected by the participants' willingness and commitment to wear them (Esliger et al., 2005). Nevertheless, studies using accelerometers will add to the understanding of the relationships between habit and PA. Second, habit was also assessed using self-report measures. Although the SRBAI, used in Study 1, is a reliable and valid instrument (Gardner et al., 2012b), its nature remains subjective. Study 2 relied on a habit scale that consisted of four automaticity items taken from the reliable and valid SRHI (Verplanken & Orbell, 2003). Nevertheless, its nature is also subjective. Third, although chances are low, the existence of seasonal effects cannot entirely be ruled out. Both current studies had a broad, but completely different, inclusion period, with baseline measurement from March to June for Study 1 and from November to March for Study 2. Nonetheless, data patterns were highly comparable, which speaks against the presence of seasonal

effects. Moreover, participants were instructed to report their PA of an average, normal week in the last month, which makes reports on weeks with a lot of rainfall or other weather extremes unlikely. Fourth, based on temporal precedence causal associations in the cross-lagged panel model are assumed. However, this assumption is not a test of causal inference. Fifth, the samples of the current studies displayed rather high levels of PA and stable mean scores on habit, which may affect the generalization of the results.

Several strengths of this study also have to be acknowledged. First, our studies were, to our knowledge, the first to model longitudinal mediated relationships between habit and PA in a cross-lagged panel design, spanning a period of one year. Second, our research populations consisted of older adults. Demographic development predictions for the near future indicate a rapid growth of the population of older adults in the western world (Christensen et al., 2009). As a large proportion of older adults are insufficiently physically active (Hallal et al., 2012; Sun et al., 2013), this points out the major relevance of stimulating PA in older adults. Insight into the working mechanisms of habit and PA may help to design stronger effective interventions to increase PA in older adults, which, ultimately, may help them to obtain many health benefits. Third, we performed SEM analyses, instead of regression analyses, which are frequently used in mediation studies. SEM analyses have the advantage of taking measurement errors into account and providing important additional information about model fit (Byrne, 2012; Schumacker & Lomax, 2010), and thus give a more complete statistical underpinning of the results (Peyrot, 1996). Fourth, we used the product of coefficients test, which provides a direct estimate of the mediation effect (Hayes, 2013; MacKinnon, 2008), and confidence intervals based on the distribution of the product, which take nonnormality of the mediation effects into account (Tofighi & MacKinnon, 2011).

In sum, the present study found indications for the existence of both PA-habit-PA paths and habit-PA-habit paths, but did not show a clear, unequivocal pattern. Somewhat more support was found for the PA-habit-PA path than for the habit-PA-habit path. More research is needed to draw more definitive conclusions.

NOTES

[1] Model fit for control group Study 1: χ^2 (88) = 269.54, p < .001, CFI = .95, TLI = .93, RMSEA = .06. Significant habit(t0)-PA(t1)-habit(t2) path: z = 1.96, p = .050, CI = [.003; .038], $\hat{a}\hat{b}_{cs}$ = .016, PME = 3.4%); nonsignificant PA(t0)-habit(t1)-PA(t2) path: z = 1.22, p = .224, CI = [-.002; .017], $\hat{a}\hat{b}_{cs}$ = .006, PME = 2.6%). Age(t0) was not a significant predictor of PA and habit on both t1 and t2 (p > .10). Less functional limitations on baseline predicted more PA on t2 (path estimate = .109, p = .005), but not on t1 (p > .10), and had a marginally significant relationship with habit on t2 (path estimate = .078, p = .051), but not on t1 (p > .10).

[2] Model fit for control group Study 2: χ^2 (88) = 206.15, p < .001, CFI = .96, TLI = .94, RMSEA = .06. Nonsignificant habit(t0)-PA(t1)-habit(t2) path: z = .91, p = .362, CI = [-.012; .040], $\hat{a}\hat{b}_{cs}$ = .011, PME = 2.2%); significant PA(t0)-habit(t1)-PA(t2) path: z = 1.85, p = .064, CI = [.003; .068], $\hat{a}\hat{b}_{cs}$ = .032, PME = 10.7%). The results from normal theory approach (i.e. the p-value) and confidence intervals based on distribution of the product are inconsequential for the PA(t0)-habit(t1)-PA(t2) path. From these two approaches the confidence intervals are most trustworthy (Hayes, 2013; Jose, 2013). Thus, the result can be interpreted as significant. Age(t0) was a significant predictor of PA on t2 (path estimate = .113, p = .027), but not on t1 (p > .10). Habit scores on t1 and t2 were not predicted by baseline age (p > .10) Functional limitations on baseline were not significantly associated with PA and habit on either t1 or t2 (p > .10).

CHAPTER 5

ARE ACTION PLANNING AND PHYSICAL ACTIVITY MEDIATORS OF THE INTENTION-HABIT RELATIONSHIP?

Rob J.H. van Bree
Aart N. Mudde
Catherine Bolman
Maartje M. van Stralen
Denise A. Peels
Hein de Vries
Lilian Lechner

Psychology of Sport and Exercise, 2016, 27, 243-251. doi: 10.1016/j.psychsport.2016.09.004

ABSTRACT

Objectives: Habit formation has been proposed as a way to ensure long-term maintenance of physical activity (PA). Although intention, action planning (AP), and PA are suggested to be determinants of PA habits, it is largely unknown how they determine PA habits. This study examined whether the relationship between intention and habit is mediated by AP and/or PA.

Methods: Two independent studies were conducted in 469 (Study 1: M_{age} = 63.07, SD = 7.61) and 322 (Study 2: M_{age} = 64.31, SD = 9.39) older adults. In both studies the older adults completed questionnaires on intention, PA, and habit at baseline, AP at three months, PA at six months, and habit at twelve months.

Results: Structural equation modeling analyses showed significant intention-PA-habit paths and nonsignificant intention-AP-habit and intention-AP-PA-habit paths in both studies.

Conclusions: The relationship between PA habit and intention was mediated by PA. Intention was neither associated with habit via AP as a single mediator, nor via AP and PA as sequential mediators. Possible conditions under which intention-AP-habit paths and intention-AP-PA-habit paths exist are discussed.

INTRODUCTION

Regular physical activity (PA) has many physical and mental health benefits (e.g. Hamer, Lavoie, & Bacon, 2014; Lee et al., 2012). A large proportion of older adults are currently insufficiently active to obtain the health benefits associated with sufficient PA (Hallal et al., 2012; Sun, Norman, & While, 2013). These health benefits can only be obtained and preserved when PA is maintained over a long period of time (Sarafino & Smith, 2014). In order to ensure long-term maintenance of health behaviors, such as PA, calls have been made to target habit formation or strengthening of existing habits in interventions (Lally & Gardner, 2013; Rothman, Sheeran, & Wood, 2009). Nevertheless, the majority of interventions to stimulate and maintain PA do not explicitly target habit formation, but assume that once intentions are translated into behavior, the behavior will gradually become habitual (Lally, Chipperfield, & Wardle, 2008).

Habits form through consistent repetition of behavior in a stable context (Kaushal & Rhodes, 2015; Lally, Van Jaarsveld, Potts, & Wardle, 2010), whereby control over the behavior is gradually transferred from deliberative thoughts to contextual stimuli (Lally, Wardle, & Gardner, 2011). These contextual stimuli consequently acquire the potential to activate behavior, so that upon encountering these stimuli, automatic, habitual responses are activated (Bargh, 1994; Orbell & Verplanken, 2010; Wood & Neal, 2009). Once habits have become strong, these responses no longer depend on supporting intentions and should thus persist even when motivation or self-control resources are lowered (Gardner, 2015; Neal, Wood, & Drolet, 2013); the habitual responses are performed in the absence of conscious control or mental effort (Verplanken, 2006; Wood, Quinn, & Kashy, 2002). As a consequence they reduce the risk of relapse (Verplanken & Wood, 2006).

Performing and repeating behavior, prerequisites for habit formation, is not as simple as it may seem at first glance (Gollwitzer & Sheeran, 2006). Many people, namely, fail to act upon their intentions (Sheeran, 2002). This intention-behavior discordance is often referred to as the intention-behavior gap (Hagger & Luszczynska, 2014; Rhodes & Yao, 2015). As behavioral repetition is a prerequisite for habit formation, the presence of an intention-behavior gap forestalls habit formation. Action planning (AP) is a recognized and frequently applied method to overcome the intention-behavior gap (Gollwitzer, 1999; Hagger & Luszczynska, 2014). AP is a vital component of the Health Action Process Approach (HAPA) model (Schwarzer, 2008). In this model AP is assumed to be a mediator between intention and behavior. AP is a post-intentional process that links behavioral responses to situational cues by specifying what, when, where, with whom, how, and how often to act in accordance with one's intention (Lippke, Ziegelmann, & Schwarzer,

2004; Sniehotta, Scholz, & Schwarzer, 2005, 2006). Upon encountering situational cues defined in the action plan, behavioral responses are supposed to be elicited without deliberation (Sniehotta, Schwarzer, Scholz, & Schüz, 2005). AP thus facilitates translation of intentions into initiation of desired behavior (Scholz, Schüz, Ziegelmann, Lippke, & Schwarzer, 2008) and results in repetition of a target behavior (Hagger & Luszczynska, 2014) and, as HAPA posits, in maintenance (Schwarzer, 2008). A meta-analysis indeed revealed an indirect effect of intention on PA through AP (Carraro & Gaudreau, 2013). Repetition of behavior in a stable context, as a result of an action plan, can, in turn, lead to habit formation, as described above (Lally et al., 2010; Verplanken, 2005; Wood & Neal, 2009).

Indeed, action plans referring to when and where to exercise were found to be predictors of exercise habit (De Bruijn, Gardner, Van Osch, & Sniehotta, 2014). Experimental studies on dental flossing found that habit formation can be promoted by forming action plans (Judah, Gardner, & Aunger, 2013; Orbell & Verplanken, 2010). In their study to encourage women at retirement age to embed balance and strength exercises into their daily routines, Fleig et al. (2016) found an increase in action planning and habit strength. Qualitative analyses indicated that action planning facilitated habit formation. Moreover, Fleig, Pomp, Schwarzer, and Lippke (2013) found a sequential indirect effect of participation in an intervention with booster sessions through action planning and exercise behavior on exercise habit strength. Furthermore, a study by Fleig, Pomp, Parschau, et al. (2013) on spontaneous use of AP (i.e. not induced by an intervention aimed at setting action plans) in two distinct populations (i.e. university students and medical rehabilitation patients) revealed that physical exercise intentions were translated into an increase of exercise habit via AP and exercise as sequential mediators. To our knowledge, this study by Fleig, Pomp, Parschau, et al. (2013) is the only study testing such a path of sequential mediators. In the same study, AP was found to be a single mediator of the relationship between intention and habit in the medical rehabilitation patients population, but not in the university student population, whereas exercise operated as a single mediator between intention and habit in the university student population, but not in the medical rehabilitation patients population (Fleig, Pomp, Parschau, et al., 2013). The current study tries to replicate the findings of Fleig, Pomp, Parschau, et al. (2013) in a general population of older adults.

To our best knowledge, to date no studies on the relationship between intention, AP, PA, and habit have been conducted in the growing general population of older adults. The current study targets adults aged 50 years or older. Insight into the working mechanisms of PA habit formation or PA habit strengthening may help to design interventions to maintain PA in older adults. The aim of the current study is to conduct structural equation

modeling (SEM) analyses to test, in a prospective design, whether the relationship between intention and (changes in) habit is mediated by AP and PA as single mediators (i.e. an intention-AP-habit path and an intention-PA-habit path, controlled for habit at baseline), and by AP and PA as sequential mediators (i.e. an intention-AP-PA-habit path, controlled for habit at baseline) (see Figure 5.1). It is hypothesized that significant mediation effects exist for the intention-AP-habit and the intention-PA-habit paths, as well as for and the intention-AP-PA-habit path. The analyses will be conducted in two independent samples of adults aged 50 years or older.

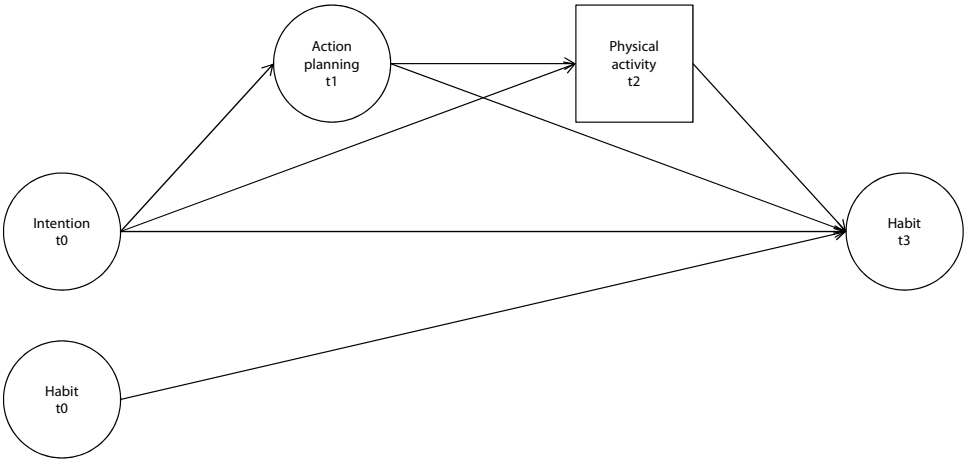

Figure 5.1 Conceptual model for the relationships among intention, action planning, PA, and habit

Note: Latent variables are represented in circles, observed variables in rectangles.

METHODS

Data of two independent studies were used. The Medical Ethics Committee of Maastricht University and the University Hospital Maastricht approved the study protocol of Study 1. That study was registered at the Dutch Trial Register (NTR920). Study 2 was approved by the Medical Ethics Committee of Atrium-Orbis-Zuyd and registered at the Dutch Trial Register (NTR2297). For both studies informed consent was obtained from all participants.

Participants and Procedures

Study 1. This study was a secondary analysis of data from a clustered randomized controlled trial (RCT) testing the efficacy of two tailored interventions aimed at promoting PA in adults aged 50 years or older (see Van Stralen, De Vries, Mudde, Bolman, & Lechner, 2009b, 2011). A wait list control condition was part of the RCT. The procedure of the RCT, including the selection, enrollment, and dropout of participants, the distribution and content of the questionnaires, and the interventions are described in detail elsewhere (see Van Stralen et al., 2008, 2011). For the current study, data were used from participants that were assigned to the control condition. These participants did not undergo any PA intervention, but only received questionnaires of the study at baseline (t0) and at three (t1), six (t2), and twelve months (t3) after baseline measurement. At the end of the study, they were given access to the intervention content.

For the control condition 2700 Dutch adults, aged 50 years or older, were invited by a written letter to participate in the study via two randomly selected Municipal Health Councils. A total of 583 adults (22%) agreed to participate and completed the baseline questionnaire. Retention rates at three, six, and twelve months were 84%, 83%, and 80% respectively.

Study 2. This study was a secondary analysis of data from a RCT that aimed to compare the effectiveness and cost-effectiveness of four tailored PA interventions for adults aged 50 years or older (for long-term effectiveness studies see Peels et al., 2013; for long-term cost-effectiveness studies see Peels et al., 2014). A wait list control condition was part of the RCT. Only data from this control condition were used in the current study. The participants received questionnaires at baseline (t0) and at three (t1), six (t2), and twelve months (t3) after baseline measurement. At the end of the study, control group participants were given access to the intervention content. The procedure of the RCT, including the selection, the participation and dropout rates, the delivery mode and content of the questionnaires, and the interventions are described in detail elsewhere (see Peels et al., 2013).

For the control condition 1850 Dutch adults, aged 50 years or older, were invited by a written letter to participate in the study via a randomly selected Municipal Health Council. A total of 411 adults (22%) agreed to participate and completed the baseline questionnaire. Retention rates at three, six, and twelve months were 77%, 75%, and 76% respectively.

Measures

Study 1. Data were collected by means of questionnaires at baseline (t0) and at three (t1), six (t2), and twelve months (t3) after baseline measurement (see Van Stralen et al. 2008, 2011 for details). For the current study, data on demographic (t0) and health-related (t0) characteristics and on intention (t0), AP (t1), PA (t0, t2) and habit (t0, t3) were used.

Age (t0), *gender (t0), body mass index (BMI; t0)*, *educational level (t0)* (dichotomized into low and medium/high), *marital status (t0)* (dichotomized into having a partner and not having a partner), and the presence of a *functional limitation (t0)* were assessed.

Items on intention, AP, and habit referred to sufficient PA, which, in accordance with the PA recommendation for people aged 50 years or older (Haskell et al., 2007; Nelson et al., 2007), was explicitly defined as being at least moderately physically active for at least 30 minutes per day on at least five days per week. Whereas participants were instructed to report their PA of an average, normal week in the last month, the items measuring intention, AP, and habit did not refer to a specific time frame.

Intention (t0) to be sufficiently physically active was assessed by three items (example: 'Are you planning to be or to stay sufficiently physically active?'). The items were adapted from the measurement of Sheeran and Orbell (1999). Answering options ranged from 'very certainly not' (1) to 'very certainly yes' (10). Cronbach's alpha was .93.

AP (t1) was measured by six statements (example: 'I plan precisely when to be physically active'). Five items were taken from the measurement of Lippke et al. (2004). One item, taken from Sniehotta, Scholz, et al. (2005) ('I plan precisely how often to be physically active') was added. Answering options ranged from 'totally disagree' (-2) to 'totally agree' (2). Cronbach's alpha was .94.

Total weekly days of sufficient PA (t0, t2) was assessed with the self-administered Dutch short questionnaire to assess health-enhancing PA (SQUASH). The overall reliability ($r_{spearman}$ = .57) and relative validity of the SQUASH in relation to Actigraph™ activity monitors ($r_{spearman}$ = .67) were reasonable in older subjects (Wagenmakers et al., 2008). A single-item question of the SQUASH was used: 'On how many days per week are you, in total, at least moderately physically active for at least 30 minutes by undertaking, for example, heavy walking, cycling, chores, gardening, sports or other moderate or vigorous physical activities?'. Although single-item self-reports may be less accurate,

studies provided support for the validity and reliability of single-item self-reports of PA (Iwai et al., 2001; Jackson, Morrow, Bowles, FitzGerald, & Blair, 2007; Li, Carlson, & Holm, 2000; Milton, Bull, & Bauman, 2011; Wanner et al., 2014; Weiss et al., 1990).

Habit (t0, t3) was measured using the Self-Report Behavioral Automaticity Index (SRBAI; Gardner, Abraham, Lally, & De Bruijn, 2012b). This scale comprises four automaticity items: 'Being sufficiently physically active is something …I do automatically, …I do without having to consciously remember, …I do without thinking, …I start doing before I realize I'm doing it'. Answering options ranged from 'totally disagree' (-2) to 'totally agree' (2). Cronbach's alpha was .86 (t0) and .86 (t3).

Study 2. Similar to the approach in Study 1, data were collected by means of questionnaires at baseline (t0) and at three (t1), six (t2), and twelve months (t3) after baseline measurement (see Peels et al., 2012 for details). Data on demographic (t0) and health-related (t0) characteristics and on intention (t0), AP (t1), PA (t0, t2) and habit (t0, t3) were used in this study.

The definition of sufficient PA and the operationalization of *intention (t0)* (Cronbach's alpha: .95), *AP (t1)* (Cronbach's alpha: .96) and *total weekly days of PA (t0, t2)* are the same as in Study 1. *Habit (t0, t3)* was measured in a slightly different way compared to Study 1. In Study 2 four automaticity items were taken from the Self-Report Habit Index (SRHI; Verplanken & Orbell, 2003). Two of these items are also part of the SRBAI (see Study 1), the other two are not. Participants had to rate four statements: 'Being sufficiently physically active is something …I do automatically, …I start doing before I realize I'm doing it …I would find hard not to do, …I have no need to think about doing'. Answering options ranged from 'totally disagree' (-2) to 'totally agree' (2). Cronbach's alpha was .89 (t0) and .86 (t3).

Analyses

In Study 1 and Study 2 the same analytical approach was used. Means and standard deviations were calculated using SPSS 23. Independent sample t-tests and Chi-square tests were conducted to test for baseline differences in age, gender, marital status, educational level, and BMI between participants that dropped out and those that did not. SEM analyses with Mplus 5.21 (Muthén & Muthén, 1998-2007) were applied to test hypothesized associations between the various constructs. Maximum likelihood estimation was used to cope with missing values. Gender, age, and marital status were control variables in all analyses. There was no need to correct for intervention effects, as only control condition data were used.

In coherence with the introduction, in which was stated that the current studies target habit formation and/or habit strengthening, only participants for whom increases in habit were possible were included in the analyses. In other words, to analyze increases in PA habit, participants with high habit baseline scores were excluded from the analyses, just as was done in the study by Fleig, Pomp, Parschau, et al. (2013), of which the current studies are replications. The exclusion criterion that was applied is an approximate of the criterion used in the study by Fleig, Pomp, Parschau, et al. (2013) (i.e. > 1 on a scale ranging from -2 to 2, whereas Fleig, Pomp, Parschau, et al. (2013) used > 4 on a scale ranging from 1 to 6). Only participants with weak or moderate habits remained in the sample. All analyses were controlled for baseline habit.

As recommended by Byrne (2012), the measurement model and structural model were constructed separately. Intention, AP, and habit were latent constructs, measured by separate indicators, as defined in the description of the questionnaire. Confirmatory factor analysis was used to test the measurement model. A minimum factor loading of .40 was applied (Stevens, 2002). Since panel data were used, identical indicators across time points were expected to correlate (Bollen, 1989; Landis, Edwards, & Cortina, 2009). Therefore, residual covariances among all identical indicators were defined a priori. The adequately defined measurement model was used for the path analyses with latent variables in the structural models (see Figure 5.1).

Model fit was assessed using a combination of fit indices. Chi-square tests were conducted to test for differences between theoretical and observed models. A good model fit is indicated by $p > .05$ (Tabachnick & Fidell, 2007). This *p*-value, however, is sensitive to large sample sizes and easily produces a statistically significant result therein (Kline, 2011). In addition, Root Mean Square Error of Approximation (RMSEA), Comparative Fit Index (CFI), and Tucker-Lewis Index (TLI) were calculated. An acceptable model fit is indicated by RMSEA < .08, CFI > .90, and TLI > .90 (Schumacker & Lomax, 2010; Van de Schoot, Lugtig, & Hox, 2012), whereas a good model fit is obtained when RMSEA < .06, CFI > .95, and TLI > .95 (Hu & Bentler, 1999). For RMSEA 90% confidence intervals were provided. A well-fitting model is indicated by an upper limit < .08 (Hooper, Coughlan, & Mullen, 2008).

Mediation effects were estimated using the product of coefficients test (e.g. MacKinnon, 2008). This test determines how much of the effect that an independent variable exerts on a dependent variable is exerted trough one or more mediator variables. To take nonnormality of the mediation effects into account 95% bias-corrected bootstrap confidence intervals (CI) were calculated (bootstrap = 5000; Hayes, 2013; Jose, 2013). The percentage mediated effect (PME) was used as an effect size to evaluate the magnitude

of the mediation effect (see MacKinnon, 2008). The completely standardized indirect effect ($\hat{a}\hat{b}_{cs}$; Preacher & Kelley, 2011) was also used as an effect size. This effect size was evaluated according to Cohen's r^2 criteria (.01 = small; .09 = medium; .25 = large; Cohen, 1988).

RESULTS

Descriptives

Study 1. High baseline habit scores (i.e. > 1 on a scale ranging from -2 to 2) were reported by 114 of 583 participants. Those participants were excluded from the analyses. Ages from the remaining 469 participants ranged from 51 to 87 years (M = 63.07, SD = 7.61). Males were slightly underrepresented (47%). About half of the participants (47%) met the PA recommendation at baseline. Functional limitations were reported by 30% of participants. Dropout at twelve months measurement was not related to baseline age, gender, marital status, and educational level. The higher the baseline BMI of participants, the more likely they were to dropout at twelve months measurement, $t(450) = 3.57$, $p < .001$. Means, standard deviations, and maximum likelihood estimated correlations are displayed in Table 5.1.

Study 2. Baseline habit measures showed that 89 of 411 participants reported a high habit score. Those participants were excluded from the analyses. Ages from the remaining 322 participants varied from 50 to 92 years (M = 64.31, SD = 9.39). Sex was nearly equally distributed (157 women, 165 men). Less than half of the participants (35%) met the PA recommendation at baseline. Chronic physical limitations were reported by 58% of participants. Dropout at twelve months measurement was not related to baseline age, gender, marital status, educational level, or BMI. Means, standard deviations, and maximum likelihood estimated correlations are displayed in Table 5.1.

Measurement models

Study 1. The measurement model showed an acceptable model fit, χ^2 (109) = 375.22, $p < .001$, CFI = .94, TLI = .93, RMSEA = .07, CI_{RMSEA} = [.06; .08]. All factor loadings exceeded the level of .40.

Study 2. The measurement model yielded an acceptable model fit, χ^2 (109) = 260.74, $p < .001$, CFI = .96, TLI = .95, RMSEA = .07, CI_{RMSEA} = [.06; .08], with all factor loadings > .40.

Table 5.1 Means, standard deviations, ranges, and maximum likelihood estimated bivariate correlations for Study 1 and Study 2

				Study 1					
		M	***SD***	**Range**	**1.**	**2.**	**3.**	**4.**	**5.**
1.	Intention t0	7.54	1.78	1 - 10	-				
2.	AP t1	.10	.87	-2 - 2	.18**	-			
3.	PA t2	4.11	1.94	0 - 7	.38***	.08	-		
4.	Habit t0	.25	.69	-2 - 1	.25***	.07	.18**	-	
5.	Habit t3	.21	.83	-2 - 2	.27***	.03	.29***	.60***	-
				Study 2					
		M	***SD***	**Range**	**1.**	**2.**	**3.**	**4.**	**5.**
1.	Intention t0	7.21	1.67	1 - 10	-				
2.	AP t1	-.59	1.04	-2 - 2	.03	-			
3.	PA t2	4.23	1.91	0 - 7	.41***	.02	-		
4.	Habit t0	.22	.78	-2 - 1	.60***	-.02	.37***	-	
5.	Habit t3	.21	.78	-2 - 2	.48***	.07	.42***	.65***	-

Note. All correlations stem from model estimations in which only the correlations depicted above and residual covariances between identical indicators across time points were defined. For Study 1 ($N = 469$) the model yielded an acceptable model fit: $\chi^2 (122) = 402.31$, $p < .001$, CFI = .94, TLI = .92, RMSEA = .07, $CI_{RMSEA} = [.06; .08]$. For Study 2 ($N = 322$) the model showed a good model fit: $\chi^2 (122) = 266.65$, $p < .001$, CFI = .96, TLI = .95, RMSEA = .06, $CI_{RMSEA} = [.05; .07]$.
t0 = baseline measurement, t1 = three months measurement, t2 = six months measurement, t3 = twelve months measurement.
* $p < .05$, ** $p < .01$, *** $p < .001$ (two-tailed).

Structural models

Study 1. The structural regression model had an acceptable model fit, χ^2 (163) = 453.75, $p < .001$, CFI = .94, TLI = .92, RMSEA = .06, CI_{RMSEA} = [.06; .07]. Habit(t3) was directly predicted by habit(t0) and PA(t2). Intention(t0) was a direct predictor of AP(t1) and PA(t2), but not of habit(t3). AP(t1) was not a significant direct predictor of PA(t2) and habit(t3) (see Figure 5.2). A significant mediation effect was found for the path intention(t0)-PA(t2)-habit(t3) (product of coefficients' z = 3.017, p = .003, CI = [.012; .049], $\hat{a}\hat{b}_{cs}$ = .068, PME = 47.0%). The $\hat{a}\hat{b}_{cs}$ indicates a small to medium effect size. The mediation effects of the paths intention(t0)-AP(t1)-habit(t3) (z = -.646, p = .518, CI = [-.016; .004], $\hat{a}\hat{b}_{cs}$ = -.007, PME = 5.0%) and intention(t0)-AP(t1)-PA(t2)-habit(t3) (z = .141, p = .888, CI = [-.001; .002], $\hat{a}\hat{b}_{cs}$ = .000, PME = 0.2%) were not significant (see Figure 5.2).[1]

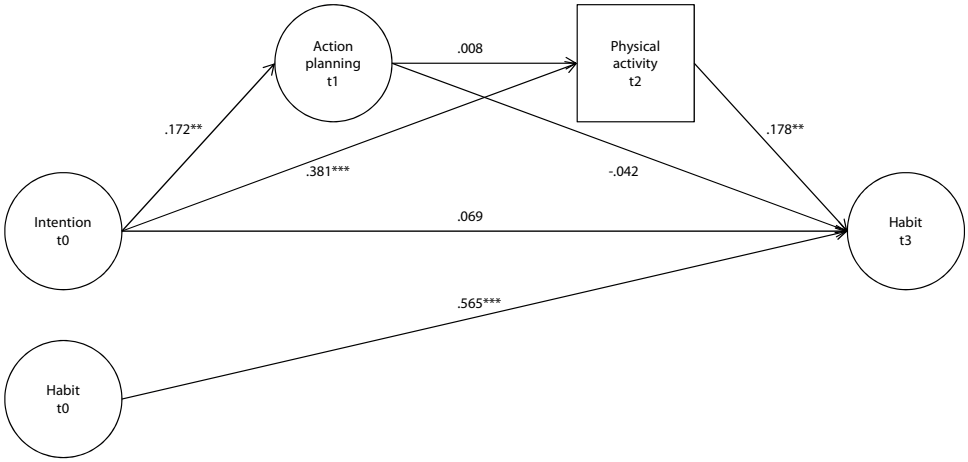

Figure 5.2 Mediation model for Study 1

Note. Model fit: χ^2 (163) = 453.75, $p < .001$, CFI = .94, TLI = .92, RMSEA = .06, CI_{RMSEA} = [.06; .07].
Latent variables are represented in circles, observed variables in rectangles; values indicate standardized maximum likelihood path estimates; control variables were age, gender, and marital status; control variables were not significantly associated with variables on t1, t2, and t3, except for age with AP (path estimate = -.101, p = .050).
t0 = baseline measurement, t1 = three months measurement, t2 = six months measurement, t3 = twelve months measurement.
* $p < .05$, ** $p < .01$, *** $p < .001$ (two-tailed)

Study 2. The model fit for the structural regression model was acceptable, χ^2 (163) = 325.41, $p < .001$, CFI = .96, TLI = .95, RMSEA = .06, CI_{RMSEA} = [.05; .06]. Habit(t0) and PA(t2) were direct predictors of habit(t3). Intention(t0) only directly predicted PA(t2). AP(t1) neither directly predicted PA(t2) nor habit(t3) (see Figure 5.3). A significant mediation effect was found for the path intention(t0)-PA(t2)-habit(t3) (z = 2.573, p = .010, CI = [.014;

.076], $\hat{a}\hat{b}_{cs}$ = .088, PME = 45.4%). The $\hat{a}\hat{b}_{cs}$ indicates a medium effect size. The mediation effects of the paths intention(t0)-AP(t1)-habit(t3) (z = .154, p = .877, CI = [-.005; .010], $\hat{a}\hat{b}_{cs}$ = .001, PME = 0.6%) and intention(t0)-AP(t1)-PA(t2)-habit(t3) (z = .050, p = .960, CI = [-.001; .002], $\hat{a}\hat{b}_{cs}$ = .000, PME = 0.0%) were not significant (see Figure 5.3).[2]

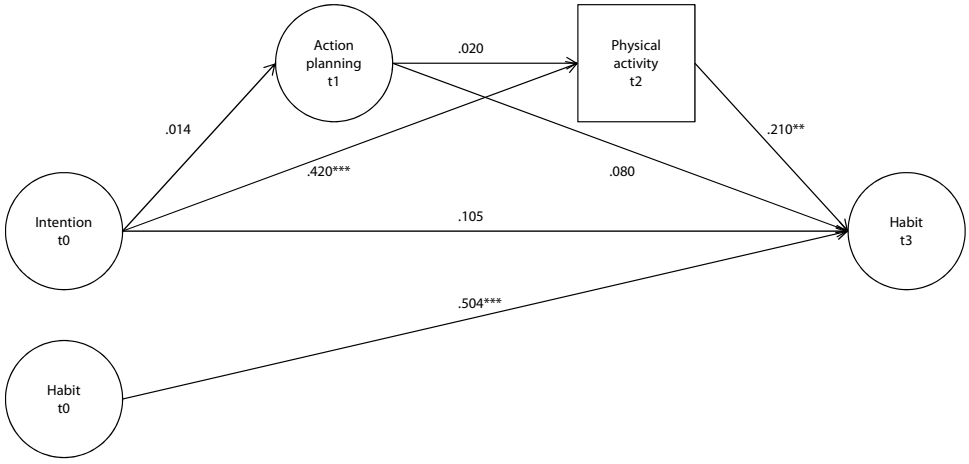

Figure 5.3 Mediation model for Study 2

Note. Model fit: χ^2 (163) = 325.41, p < .001, CFI = .96, TLI = .95, RMSEA = .06, CI_{RMSEA} = [.05; .06].
Latent variables are represented in circles, observed variables in rectangles; values indicate standardized maximum likelihood path estimates; control variables were age, gender, and marital status; control variables were not significantly associated with variables on t1, t2, and t3, except for age with AP (path estimate = -.152, p = .024).
t0 = baseline measurement, t1 = three months measurement, t2 = six months measurement, t3 = twelve months measurement.
* p < .05, ** p < .01, *** p < .001 (two-tailed).

DISCUSSION

In two prospective studies in older adults the hypotheses were tested that the relationship between intention and habit is mediated by AP and PA as single mediators (i.e. an intention-AP-habit path and an intention-PA-habit path), and by AP and PA as sequential mediators (i.e. an intention-AP-PA-habit path). Results from both studies only confirmed the hypothesis that PA mediates the intention-habit relationship; no significant mediation effect was found for the intention-AP-habit path or the intention-AP-PA-habit path.

The majority of interventions to stimulate and maintain PA assume the existence of an intention-behavior-habit path. That is, they do not explicitly target habit formation, but assume that once intentions are translated into repeated behavior, the behavior will gradually become habitual (Lally et al., 2008). Fleig, Pomp, Parschau, et al. (2013) found a significant intention-exercise-habit path in their study in university students, but not in their study in rehabilitation patients. The current study found a significant intention-PA-habit path in two different samples of older adults. This significant mediation effect indicates that there is a working mechanism of intention affecting habit through PA. This result supports the abovementioned assumption underlying many interventions. However, it must be noted that a small decrease in habit was found in the current studies. Merely filling out questionnaires may have raised awareness, which, in turn, may have disturbed the automatic, habitual performance of PA to some extent.

In the current studies the relationship between intention and habit was not significantly mediated by AP. The weak associations between intention and AP and the absence of significant associations between AP and habit may have contributed to the nonsignificance of this single mediator path. The standardized maximum likelihood estimates of intention on AP were low (Study 1) to very low (Study 2). An explanation for this finding may be that the interval of three months between the measurement of intention and AP was too long. It can be argued that people who already have the intention to become (more) physically active generally do not wait three months before starting to translate their intentions into action plans. A recent study in older adults found a significant intention-AP relationship when using an interval of seven weeks between measurement of intention and measurement of AP (Wolff, Warner, Ziegelmann, Wurm, & Kliegel, 2016). Shorter intervals than three months are therefore recommended in future research. Furthermore, Allain et al. (2005) and Sorel and Pennequin (2008) found that older adults had more difficulty developing logical strategies and making a plan than younger adults. Although these studies did not specifically target AP as operationalized in the current study, the decline in executive functioning during the aging process that these studies revealed may go together with less or incomplete spontaneous AP in older adults, which, in turn, may explain why intention in the current studies was scarcely or even not translated into AP. This idea finds support in the study by Allan, Johnston, and Campbell (2011) that found that respondents with good executive control, which includes planning abilities, were more likely to achieve on their intentions than those with poor executive control. Less or incomplete AP may explain the absence of a significant relationship between AP and habit. Unfortunately, this could not be tested in the current studies, as control over complete AP can only be achieved in experiments. Another viable explanation for the weak association between intention and AP may be that older adults, especially those who are retired, have more

leisure time and, therefore, experience less need to plan their activities (Fleig et al., 2016; French, Olander, Chisholm, & McSharry, 2014; Warner, Wolff, Ziegelmann, Schwarzer, & Wurm, 2016).

The sequential mediating path from intention via AP and PA to habit was not significant, indicating that for a general population of older adults the intention-PA-habit path cannot be extended with AP as mediator. The weak associations between intention and AP and between AP and habit, as described and discussed above, have most probably contributed to the absence of a significant sequential mediator path. In contrast to the two current studies, Fleig, Pomp, Parschau, et al. (2013) found a significant intention-AP-exercise-habit path in both university students and rehabilitation patients. However, there are methodological differences between the current studies and the studies by Fleig, Pomp, Parschau, et al. (2013). In the current studies PA was hypothesized to be a mediator, while Fleig, Pomp, Parschau, et al. (2013) used exercise. The latter behavior is more narrowly defined than the former. That is, PA incorporates exercise, which usually requires good planning because it often takes place on predetermined times and places, as well as activities for which people generally do not make action plans, such as cycling to a supermarket and gardening. AP may have a stronger influence on narrowly defined exercise than on broadly defined PA. Moreover, the time lags used in the current studies were generally longer than those used by Fleig, Pomp, Parschau, et al. (2013). As correlations tend to decrease when temporal distance between measurement points increases (McEachan, Conner, Taylor, & Lawton, 2011; Sutton, 1994), the time lags used in the current studies may have reduced the magnitude of the AP-PA relationship and, consequently, may have contributed to the absence of a significant intention-AP-PA-habit path.

Besides methodological differences there are differences in population characteristics between the current studies and the studies by Fleig, Pomp, Parschau, et al. (2013) that may have impacted the results. Because of differences in operationalization of the constructs and in measurement scales, comparing absolute values is not a valid strategy. Making comparisons on relative positions, such as above mean and around midscale, is legitimate. To begin with, the mean intention scores of the participants in the current studies were moderately high, whereas in the studies by Fleig, Pomp, Parschau, et al. (2013) the mean intention score was low for university students and around midscale for rehabilitation patients. A meta-analysis on spontaneous AP for PA showed that intention moderates the effect of AP on PA both linearly and quadratically (Carraro & Gaudreau, 2013). The linear moderation revealed that as intention scores increased, the strength of the relation between AP and PA decreased. The quadratic moderation showed that the effect of AP on PA is stronger when levels of intention are either lower

or higher than moderately high levels of intention. Thus, the moderately high mean intention scores in the current studies may have attenuated the association between AP and PA. Unfortunately, testing whether these moderation effects substantiate in the current data was beyond the scope of the current studies.

In second place, the mean score on PA in the current studies was rather high, whereas in both studies by Fleig, Pomp, Parschau, et al. (2013) the mean scores on exercise were low. From a recent meta-analysis it is known that the effect of experimentally induced AP on PA is larger for sedentary samples than for active samples (Carraro & Gaudreau, 2013). Although this meta-analysis did not test this moderation effect for observational studies, there is no compelling reason why this effect should not exist in nonexperimental processes. Both experimentally induced and spontaneous AP help initiate action (Sniehotta, Schwarzer, et al., 2005). Highly active people have already taken action and may be more concerned with overcoming obstacles to stay active over time (i.e. coping planning; Sniehotta, Schwarzer, et al., 2005). Thus, AP may be less relevant for highly active people. The rather high level of PA in the current studies may have weakened the association between AP and PA. In addition, whereas in the current studies AP was operationalized as a conditional measure (e.g. planning conditions, such as when and where, under which to be physically active), PA was unconditionally operationalized (i.e. level of PA). This difference may also have attenuated the association between AP and PA in the current studies (Sniehotta, 2009).

Furthermore, in their meta-analysis Bélanger-Gravel, Godin, and Amireault (2013) revealed that AP interventions have a positive effect on PA in university student samples and in clinical samples, but not in the general population of adults. Although the current studies were not intervention studies conducted in a general population of adults, but observational studies in a general population of older adults, the composition of the samples may nevertheless have caused different results compared to the studies by Fleig, Pomp, Parschau, et al. (2013).

Another population characteristic of importance is age. Carraro and Gaudreau (2013) found a moderating effect of age on the association between AP and PA, comprising an attenuating influence when age is higher. This effect may reflect that remembering to perform future actions is sensitive to age (Park, 1999). It may also reflect, as mentioned above, that older adults, especially those who are retired, experience less need to plan their activities. In line with this reasoning, Caudroit, Stephan, and Le Scanff (2011) found that a combined measure of action and coping planning did not mediate the intention-PA relationship in a sample of retired older respondents. The mean age in the current

studies is considerably higher than in the studies by Fleig, Pomp, Parschau, et al. (2013), which may explain the discrepancy in results. The possible effect of age demonstrates the value of replication studies in different age groups.

In sum, although the two current studies did not find a significant intention-AP-PA-habit path, there may be conditions under which such a path does exist for general populations of older adults. In order to gain better insight into the role of AP and PA as sequential mediators in the process of habit formation, it is recommended to test this path in both observational and intervention studies, with variations in time lags and in population characteristics.

Two other directions for future research emerge from this study. First, because habit formation is important for many health behaviors (Lally & Gardner, 2013), it is recommended to test the hypothesis about sequential mediation for different health behaviors. Second, beyond the possible influence of AP on PA and habit, an important conceptual issue concerns the specific role of coping planning (CP) in the sequence from intention via PA to habit. CP is a self-regulation strategy that includes a detailed planning on how to overcome barriers that might hinder the implementation of one's behavioral intentions (Scholz et al., 2008; Ziegelmann, Lippke, & Schwarzer, 2006). Because CP is considered important for adherence (Sniehotta, Schwarzer, et al., 2005), CP may be an important determinant of habit formation. Hence, it is recommended to examine whether intention-CP-behavior-habit paths and intention-AP-CP-behavior-habit paths exist for several health behaviors. Moreover, one could hypothesize that only those with sufficient CP succeed in translating PA into habit. It is recommended to examine whether CP operates as a moderator of the PA-habit relationship.

Some limitations of the present studies have to be addressed. First, a self-report single-item measure of PA was used. Although studies provided support for the reliability and validity of single-item self-reports of PA (Iwai et al., 2001; Jackson et al., 2007; Li et al., 2000; Milton et al., 2011; Wanner et al., 2014; Weiss et al., 1990), self-reports may be both higher and lower than true levels of PA (Prince et al., 2008), as they may suffer from memory biases (Smyth & Stone, 2003; Stone & Shiffman, 2002). The intercorrelations between scores obtained from various extensive PA questionnaires and scores obtained from assessments based on one item, are often weak (.15 - .32; Weiss et al., 1990) to moderate (.46 - .54; Milton et al., 2011) for respondents aged 55 years or older. The intercorrelation between our single-item score and the total score (i.e. days per week) from the lengthy version of the SQUASH was .40 (t0) and .39 (t2) for Study 1 and .43 (t0) and .36 (t2) for Study 2, which can be characterized as moderate (Cohen, 1988). In order to overcome limitations of single-item measures of PA the use of accelerometers

in future studies is recommended, as they provide objective data (Murphy, 2009; Pettee, Storti, Ainsworth, & Kriska, 2009). Second, the terminology used to measure different constructs was not entirely similar for all constructs. The items measuring intention and habit referred to being sufficiently physically active. The questionnaire provided an explicit definition of sufficient PA that was repeated several times. Slightly deviating from this definition, action planning items focused on being physically active. PA was operationalized as the number of days per week that respondents were at least moderately physically active for at least 30 minutes per day (i.e. the number of days of sufficient PA). The imperfect correspondence in terminology may have attenuated relationships between these constructs. Third, although the prospective design allowed specification of the temporal order of variables in accordance with the theoretical framework, this design cannot prove causality (Hayes, 2013). Fourth, the data stem from control groups with high levels of intention and rather high levels of PA, which may affect the generalization of the results.

Several strengths of these studies also have to be acknowledged. First, our study was the first to test the intention-AP-PA-habit path in a general population of older adults, applying a prospective design that spanned one year. Second, our research population consisted of older adults. The large proportion of older adults that are insufficiently physically active (Hallal et al., 2012; Sun et al., 2013) linked to the predicted life expectancy increases in developed countries (Christensen, Doblhammer, Rau, & Vaupel, 2009) point out the major relevance of gaining insight into the working mechanisms of PA and PA habit formation in older adults. Insight into these working mechanisms may help to design interventions to increase PA in older adults. Third, we performed SEM analyses, instead of regression analyses, which are frequently used in mediation studies. SEM analyses have the advantage of taking measurement errors into account (Byrne, 2012; Schumacker & Lomax, 2010). Furthermore, they allow the evaluation of entire models, expressed in model fit indices, which lends a higher-level perspective to the analyses and a more complete statistical underpinning of the results (Kline, 2011). Fourth, we used the product of coefficients test, which provides a direct estimate of the mediation effect (Hayes, 2013; MacKinnon, 2008).

In sum, the two presented studies in older adults showed a significant intention-PA-habit path, a nonsignificant intention-AP-habit path, and a nonsignificant intention-AP-PA-habit path. More research on these mediation paths is recommended in order to gain a deeper insight into the process of habit formation.

NOTES

[1] In order to provide a complete picture the analyses were also conducted without excluding participants with high habit scores. The same significant and nonsignificant paths were found. Results: χ^2 (163) = 469.68, $p < .001$, CFI = .95, TLI = .94, RMSEA = .06, CI_{RMSEA} = [.05; .06]; significant intention(t0)-PA(t2)-habit(t3) path: $z = 3.487$, $p < .001$, CI = [.017; .054], $\hat{a}\hat{b}_{cs} = .079$, PME = 73.2%.

[2] In order to provide a complete picture the analyses were also conducted without excluding participants with high habit scores. The same significant and nonsignificant paths were found. Results: χ^2 (163) = 349.76, $p < .001$, CFI = .96, TLI = .95, RMSEA = .05, CI_{RMSEA} = [.05; .06]; significant intention(t0)-PA(t2)-habit(t3) path: $z = 3.534$, $p < .001$, CI = [.028; .089], $\hat{a}\hat{b}_{cs} = .120$, PME = 86.9%

CHAPTER 6

GENERAL DISCUSSION

GENERAL DISCUSSION

The aim of this thesis was to unravel longitudinal relationships between habit and physical activity (PA). For this aim, four studies in older adults were conducted, in which different relationships between habit and PA were modeled.

The first study (Chapter 2) examined whether habit moderates the relationship between intention and PA. In other words, it was investigated whether the relationship between intention and PA is dependent on the level of habit strength. The hypothesis was set that intention is a predictor of PA at lower levels of habit strength, but not at higher levels of habit strength. The study was conducted within the framework of the theory of planned behavior (TPB; Ajzen, 1991) and the attitude-social influences-efficacy model (ASE; De Vries, Backbier, Kok, & Dijkstra, 1995; De Vries, Dijkstra, & Kuhlman, 1988). As the ASE model is largely comparable to the TPB, both models were used without distinction throughout this thesis (see Chapter 2 for more information).

The TPB/ASE framework was also used in the second study (Chapter 3). That study targeted the question why prior behavior is a good predictor of later behavior, even after TPB/ASE variables have been taken into account. This question is known as the residual variance problem (Ajzen, 2002). Habit has been proposed as a solution to this problem (e.g. Aarts, Verplanken, & Van Knippenberg, 1998; Sutton, 1994). That is, prior behavior is proposed to exert its influence on later behavior through habit. In this role habit is called a mediator (Hayes, 2013). In the second study it was tested whether habit mediates the relationship between prior and later PA.

In order to disentangle the longitudinal relationship between habit and PA in more depth, the third study (Chapter 4) aimed to extend current knowledge about longitudinal mediated relationships between habit and PA by examining whether habit mediates the relationship between prior and later PA, while PA simultaneously mediates the relationship between prior and later habit. It was hypothesized that both mediation effects occur simultaneously.

In one of the two mediation paths that were tested in the third study habit was modeled as an outcome variable. Habit also appeared in this latter role in the fourth study (Chapter 5). This study tested three longitudinal paths from intention to habit, using action planning (AP) and PA both as single and as sequential mediators (i.e. an intention-AP-habit path, an intention-PA-habit path, and an intention-AP-PA-habit path). The hypothesis was set that all three paths exist.

In this general discussion main findings are addressed, methodological issues are discussed, and implications for practice and directions for future research are indicated.

MAIN FINDINGS

The studies in this thesis targeted three potential roles of habit in its longitudinal relation to PA: habit as moderator (Chapter 2), habit as mediator (Chapter 3 and 4), and habit as outcome variable (Chapter 4 and 5). The main finding of this thesis is that habit plays all three roles. Habit was found to be a moderator of the intention-PA relationship (Chapter 2), a mediator between prior and later PA (Chapter 3 and 4), and an outcome variable in habit-PA-habit paths and intention-PA-habit chains (Chapter 4 and 5). How can these findings be integrated? This question is the central topic of the discussion below.

The first research question that was addressed in this thesis was whether habit forms a boundary condition for the intention-PA relationship within the framework of the TPB/ASE model (Ajzen, 1991; De Vries et al., 1988, 1995). Indeed, baseline habit was found to be a moderator of the relationship between baseline intention and follow-up PA (Chapter 2). Intention predicted PA in older adults with a low to medium habit strength towards PA, but not in those who had a strong habit. Based on this moderation effect it was recommended to incorporate habit into the TPB/ASE model. The recommendation to incorporate habit into the TPB/ASE model was also given based on the second study of this thesis (Chapter 3), in which post-intentional habit was found to be a mediator of the relationship between prior and later PA. Although the TPB/ASE model does not preclude addition of new determinants (Ajzen, 1991, 2015a; De Vries et al., 1988, 1995; Fishbein & Ajzen, 2010), variables should only be added with caution and after careful deliberation (Fishbein & Ajzen, 2010).

For any proposed addition to the TPB/ASE model Fishbein and Ajzen (2010) describe five criteria that should be met. The first criterion concerns the principle of compatibility (Fishbein & Ajzen, 2010) that demands that all variables are defined at the same level of generality or specificity (Ajzen, 2011a). The measures of habit and PA in this thesis meet this criterion, as they both refer to the international PA recommendation (Haskell et al., 2007; Nelson et al., 2007) to be at least moderately physically active for at least 30 minutes per day on at least five days per week. The second criterion demands that change in any proposed additional variable produces change in intention or behavior (Fishbein & Ajzen, 2010). To our knowledge, there are no studies examining causal paths between change in habit and change in PA. It would be worthwhile to investigate such paths in future research. To some extent, however, habit does meet the second

criterion. The second and third study of this thesis (Chapter 3 and 4) namely show that habit predicts later PA while controlling for prior PA. In line with this result another study found that habit predicts changes in exercise (Kaushal, Rhodes, Meldrum, & Spence, 2017). According to the third criterion, proposed additional variables should be conceptually independent of all TPB/ASE variables (Fishbein & Ajzen, 2010). Habits are undeniably conceptually independent, as they typically operate outside awareness, at an automatic level (Verplanken & Orbell, 2003; Gardner, 2012), while TPB/ASE variables relate to deliberative processing of available information (Conner & Sparks, 2005). The distinction between automatic and deliberative processes, combined with the recognition that both processes exert unique influence on behavior, is the key characteristic of dual-process models (Evans, 2008; Hagger, 2016; Quinton & Brunton, 2017). The fourth criterion prescribes that the variable considered for addition should be applicable to a wide range of behaviors (Fishbein & Ajzen, 2010). For habits this criterion is undoubtedly met. Habits have been shown to be valuable constructs in many different domains, ranging from environmentally sustainable behavior (e.g. Kurz, Gardner, Verplanken, & Abraham, 2015; Verplanken & Roy, 2015) to clinical psychology (Ferreira, Yücel, Dawson, Lorenzetti, & Fontenelle, 2017; Watkins & Nolen-Hoeksema, 2014), and from consumer behavior (e.g. Olsen, Tudoran, Brunsø, & Verbeke, 2013; Wood & Neal, 2009) to health psychology (e.g. Albery, Collins, Moss, Frings, & Spada, 2015; Hamilton, Orbell, Bonham, Kroon, & Schwarzer, 2018; Kaushal, Rhodes, Spence, Meldrum, 2017; Wouters et al., in press). Finally, the fifth criterion requires that the proposed additional variable should consistently improve the prediction of intentions or behavior (Fishbein & Ajzen, 2010). Habits typically explain additional variance in health behaviors over and above TPB/ASE variables. For instance, increases in explained variance after adding habit to the TPB/ASE model were found for adherence to asthma medication (ΔR^2 = 9%; Bolman, Arwert, & Völlink, 2011), alcohol consumption (ΔR^2 = 6%; Norman, 2011), fruit consumption (ΔR^2 = 3%; De Bruijn, 2010), consumption of saturated fat (ΔR^2 = 1%; De Bruijn, Kroeze, Oenema, & Brug, 2008), and active transportation (ΔR^2 = 1-7%; De Bruijn & Gardner, 2011; De Bruijn, Kremers, Singh, Van den Putte, & Van Mechelen, 2009). Adding interaction terms of habit and intention generally increases the percentage explained variance with another 1-4% (e.g. De Bruijn, 2010; De Bruijn et al., 2008, 2009; De Bruijn & Gardner, 2011). Increases in explained variance were not reported yet for the first and second study of this thesis, due to the statistical approach in which models were tested as a whole instead of assessing the contribution of individual determinants to the percentage explained variance. Additional analyses showed that habit accounted for an increase in percentage explained variance of 2% in the first study of this thesis (hierarchical linear regression analysis using SPSS 25, applying listwise deletion of cases with missing values, not including an interaction term because the first study

did not test a linear moderation effect), and of 1-3% in the second study of this thesis (analysis with Mplus 5.21, acceptable model fits, larger increases in analyses that used the Self-Report Habit Index (SRHI; Verplanken & Orbell, 2003) instead of the Self-Report Behavioral Automaticity Index (SRBAI; Gardner, Abraham, Lally, & De Bruijn, 2012b), and in analyses that were conducted in the control group alone instead of the total group). These percentages are in line with the abovementioned studies. It can be concluded that habit also meets the fifth criterion set by Fishbein and Ajzen (2010). In sum, habit meets the criteria listed above to such a large extent that it is justified to recommend incorporation of habit into the TPB/ASE model.

How and where should habit be incorporated into the TPB/ASE model? As a moderator that is concurrently assessed with intention and that exerts its effect on the intention-PA relationship (Chapter 2)? Or as a post-intentional predictor of PA (Chapter 3)? The typical approach in several studies in different domains that targeted the addition of habit to the TPB/ASE model, was to assess habit at the same time as intention and to test subsequently whether habit operates as a moderator (e.g. De Bruijn, 2010; De Bruijn et al., 2008, 2009; De Bruijn & Gardner, 2011; De Bruijn & Rhodes, 2011; De Bruijn, Rhodes, & Van Osch, 2012; Norman, 2011). In addition, various other studies that were conducted within the framework of the TPB/ASE model also measured habit at the same time as intention, but used habit only as a predictor and did not test interaction effects with intention (e.g. Bolman et al., 2011; Brug, De Vet, De Nooijer, & Verplanken, 2006; Reinaerts, De Nooijer, Candel, & De Vries, 2007). All these studies, however, do not preclude the incorporation of habit into the TPB/ASE model in the post-intentional phase. To our knowledge, there are no studies that prove that one role of habit is dominant over the other. Therefore, the most plausible answer to the questions how and where habit should be incorporated into the TPB/ASE model seems to be: both as a moderator that is concurrently assessed with intention and as a post-intentional predictor. This double role reveals that habit is a relevant construct in different phases that precede PA. Both roles indicate that habits have to be taken into account when explaining and predicting PA and when designing PA interventions based on the TPB/ASE model. This conclusion most probably also applies to the Integrated Change Model (I-Change; De Vries, 2017; De Vries et al., 2003; De Vries, Mesters, Van de Steeg, & Honing, 2005), which is developed from the TPB/ASE model and integrates ideas from various social cognitive models for behavior change (Michie, West, Campbell, Brown, & Gainforth, 2014), but does not explicitly incorporate habits yet. Incorporation of habit in the TPB/ASE model, but also in the I-Change model, would transform these social cognitive models into dual-process models. Dual-process models not only account for explicit, conscious influences on behavior, but also for implicit, unconscious influences (Evans, 2008; Hagger, 2016; Quinton & Brunton, 2017). Recognizing the influence of habit on PA, in addition to

explicit, intentional influences, will result in a more comprehensive understanding of PA (Hagger & Chatzisarantis, 2014), especially when habits are incorporated into the TPB/ASE model in different roles.

Different roles of habit in relation to PA were also found in the third study of this thesis (Chapter 4), in which PA-habit-PA paths and habit-PA-habit chains were hypothesized. Indications for the existence of both hypothesized mediation effects were found, but no clear, unequivocal pattern appeared. In this third study, habit appeared in three roles at three different measurement points: habit as a predictor of subsequent PA (first measurement point), habit as a mediator between prior and later PA (second measurement point), and habit as the endpoint or outcome variable of a mediation chain (third measurement point). The same three roles were fulfilled by PA. These different roles for both habit and PA indicate continuous, reciprocal influence between habit and PA; habit and PA are to a large extent intertwined. PA habits sustain over time through PA, while PA sustains over time through PA habits.

Habit was modeled as an outcome variable in the fourth study of this thesis (Chapter 5), in which nonsignificant intention-AP-habit and intention-AP-PA-habit paths, and significant intention-PA-habit paths were found (see Chapter 5 for a comprehensive discussion of the nonsignificant paths). The existence of intention-PA-habit paths is often assumed in PA interventions, but rarely explicitly targeted. That is, the majority of PA interventions assume that once intentions are translated into repeated PA, PA will gradually become habitual (Lally, Chipperfield, & Wardle, 2008). The findings of this fourth study support this assumption. The importance of habit as an outcome variable lies in the close ties between habit and long-term maintenance of PA (Rothman, Sheeran, & Wood, 2009). As long-term maintenance of health behaviors is the goal of most health promotion interventions, healthy habits are particularly desired outcomes.

To summarize, the four studies of this thesis show that the longitudinal relationship between habit and PA is at least threefold. Habit is a moderator of the intention-PA relationship, a mediator between prior and later PA, and an outcome variable in habit-PA-habit paths and intention-PA-habit chains. There is continuous, reciprocal influence between habit and PA. Habit exerts an effect on PA over and above social cognitive influences on PA, indicating that a dual-process view on PA provides a more comprehensive understanding of PA than a sole social cognitive view (Hagger & Chatzisarantis, 2014). It is recommended to incorporate habit into the TPB/ASE model, transforming this social cognitive model into a dual-process model. In contrast to social cognitive constructs habit does not have a single, phase-specific position in this model when explaining, predicting, and influencing PA, but exerts its effect on PA both as

a moderator that is assessed at the same time as intention and as a post-intentional predictor. Furthermore, habit plays a role in the phase following PA, both as a mediator in PA-habit-PA chains and as and an outcome variable. In all, habit is both past, present, and future.

METHODOLOGICAL ISSUES

The results and conclusions of this thesis should be interpreted in light of some methodological issues regarding study design, study population, dropout, PA measurement, and habit measurement.

Study design

All studies in this thesis used data from one or two clustered randomized controlled trials (RCT) in older adults (see Van Stralen, De Vries, Mudde, Bolman, & Lechner, 2009b, 2011; Peels et al. 2013, 2014). Both RCT's had a longitudinal design with four measurement points spread over a period of one year. This design is a major strength of the studies in this thesis, as it enabled gaining insight into longitudinal relations with rather long time intervals between measurement points. However, with measurement points at baseline and at three, six, and twelve months after baseline, the measurement points were not evenly distributed over the year. It was, however, possible to consistently model a temporal distance of six months between habit and PA. As a consequence, interpretation of relationships between these two variables has not been impeded by time intervals of different length. In itself the long time intervals used in the studies in this thesis may well have attenuated the magnitude of the relationships that were found between variables, because correlations tend to decrease when temporal distance between measurement points increases (McEachan, Conner, Taylor, & Lawton, 2011; Sutton, 1994).

The use of a second dataset in the third and fourth study in this thesis (Chapter 4 and 5) is a major strength of those studies. The use of two datasets enabled replication of findings, which lends the findings more nuance in case of partial disconfirmation (i.e. the third study of this thesis; Chapter 4) and more credibility in case of confirmation (i.e. the fourth study of this thesis; Chapter 5). As such, replication contributes to a better understanding of habit's relation to PA.

Study population

While most habit research has been conducted in student populations, the studies in this thesis targeted older adults, which can be considered a strength of this thesis. Targeting older adults in research into habit's relation to PA serves theory by contributing to a more comprehensive understanding of habit's role in relation to PA in other than student populations, and serves practice by contributing to an evidence base on which interventions to promote PA in older adults can be built.

Via Municipal Health Councils older adults (8500 in the first RCT and 13666 in the second RCT), aged 50 years and older, were invited to participate in the studies. The initial response rates of 23% (22% for control group alone; see Van Stralen et al., 2011) and 16% (22% for control group alone; see Peels et al., 2014) were not high. Nevertheless, the size of the study populations (i.e. 1976 and 2140 older adults for the first and second RCT respectively) has lent power to the statistical analyses and is, as such, a strength of the studies. Older adults that agreed to participate had rather high intentions towards PA. This can potentially be explained by the relatively long baseline questionnaire that had to be completed before participants could be included in the studies (Peels, 2014). Completing long questionnaires demands motivation, which may have resulted in self-selection. Furthermore, participants showed compliance rates with the PA guideline (i.e. 51% and 44% respectively) that were lower than those of the general population of older Dutch adults (i.e. about 60%; Centraal Bureau voor de Statistiek, 2016). As a consequence, the generalizability of the study findings to other populations, such as populations that are less motivated or have higher compliance rates with PA guidelines, may be diminished.

With regard to habit, scores in both RCT's were slightly above midscale. How does this compare to other studies? While a study on PA in older adults found habit scores above midscale (Arnautovska, Fleig, O'Callaghan, & Hamilton, 2017), findings in studies on PA in student and adult populations are mixed, with some studies reporting habit scores above midscale (Allom, Mullan, Cowie, & Hamilton, 2016) and other studies finding scores slightly below midscale (De Bruijn & Rhodes, 2011; Rhodes & De Bruijn, 2010; Rhodes, De Bruijn, & Matheson, 2010). Research on exercise in student and adult samples yielded habit scores above midscale (Fleig, Pomp, Schwarzer, & Lippke, 2013; Gardner & Lally, 2013; Verplanken & Melkevik, 2008), as well as slightly below midscale (De Bruijn, Rhodes, et al., 2012; Fleig, Pomp, Parschau, et al., 2013). In sum, the habit scores found in the studies in this thesis are no exception and do not seem to limit the generalizability of the findings.

Dropout

Considerable and selective dropout was noted in both RCT's. The twelve months dropout rate in the first RCT was 32%. Participants that were assigned to one of the intervention conditions were more likely to dropout at all times of follow-up measurement than control group participants (Van Stralen, 2010). This is in line with a review on dropout in health behavior change interventions that found that higher dropout rates in intervention conditions are not uncommon (Crutzen, Viechtbauer, Spigt, & Kotz, 2015). Participants in the intervention condition perhaps had higher expectations than control group participants in terms of change in PA. If these expectations were not met, then these participants might have been less motivated to complete follow-up measurements (Crutzen et al., 2015; Van Stralen, 2010). Selective dropout at six months measurement was noted for those with a higher baseline body mass index (BMI) and for those who did not have a partner. This latter characteristic was also associated with dropout at twelve months measurement. There was no selective dropout for age, gender, educational level, and functional limitations. Concerning the core constructs of this thesis (i.e. habit and PA) selective dropout was noted at six and twelve months measurement. Dropout was predicted by lower baseline PA and lower baseline SRHI-habit, but not for baseline SRBAI-habit. In addition, lower baseline intention was associated with dropout at twelve months measurement.

The dropout rate of the second RCT was 41% at twelve months measurement. Being assigned to an intervention condition (Peels, 2014) and having a higher baseline BMI were associated with dropout at all times of follow-up measurement. Participants with a lower age were more likely to dropout at six and twelve months measurement. There was no selective dropout for gender, educational level, having a partner, and functional limitations. Lower baseline levels of habit (measured with four automaticity items, see Chapter 4 and 5), PA and intention were associated with dropout at all times of follow-up measurement.

The high and selective dropout in both RCT's is a limitation of the current thesis that may have two potential consequences. First, dropout of participants with lower levels of baseline habit, PA, and intention may have resulted in decreases in variance in follow-up measures of these variables, which may have attenuated the strength of the relationships between these variables that were found in the studies in this thesis. Second, selective dropout may restrict the generalizability of the findings of this thesis. Based on the results of dropout analyses, caution is warranted when generalizing findings of this thesis to less motivated and less active populations with lower levels of habit. However, whereas conclusions about selective dropout are based on significant results of statistical tests with high power, generalizability should also weigh the clinical

or practical significance of differences between those who dropped out and those who did not. The maximum difference that was found between those two groups was .20 for habit (scale range -2 to 2), .28 for PA (scale range 0 to 7), and .37 for intention (scale range 1 to 10). From a practical perspective these differences are rather small and may not justify restrictions in generalizability.

PA measurement

A single-item self-report measure of PA was used in the studies in this thesis. Because of their low cost and convenience it is often most feasible to assess PA through self-report in large-scale studies (Helmerhorst, Brage, Warren, Besson, & Ekelund, 2012; Vanhees et al., 2005). Although studies provided support for the reliability and validity of single-item self-reports of PA (e.g. Milton, Bull, & Bauman, 2011; Wanner et al., 2014; Weiss et al., 1990), PA self-reports may be prone to measurement error (Prince et al., 2008) and memory biases (Smyth & Stone, 2003; Stone & Shiffman, 2002). The use of accelerometers overcomes problems with recall and memory bias, as they provide objective data (Murphy, 2009; Ndahimana & Kim, 2017; Pettee, Storti, Ainsworth, & Kriska, 2009). Perhaps the use of accelerometer measures of PA would have led to other conclusions about the relationship between habit and PA. Although the use of accelerometers in future studies is recommended, it is important to realize that accelerometers are also not without limitations. They can, for instance, not accurately detect PA in situations where much of the body remains stationary (e.g. cycling or arm movements in resistance training; e.g. Andre & Wolf, 2007; Esliger, Copeland, Barnes, & Tremblay, 2005; Hendelman, Miller, Baggett, Debold, & Freedson, 2000; Lee & Shiroma, 2014) and they are more expensive than PA questionnaires (Vanhees et al., 2005). Nevertheless, studies using accelerometers will add strongly to the understanding of the relationships between habit and PA.

Habit measurement

In the studies in this thesis PA habits were assessed. PA habits are habits for a behavior that is complex and multidimensional (Troiano, 2009). How does this complexity relate to habits? In comparison to simple actions, such as pressing a light switch, that consist of few behavioral subcomponents, PA is a complex behavior with a lot of subcomponents. For instance, when going for a run, people have to perform many actions in sequence, such as putting on sportswear, leaving the house, travelling to the sports location, running, travelling home, and entering the house (see Gardner, Phillips, & Judah, 2016). Can such complex sequences of subcomponents be a habit? Can they be performed completely automatic? There is evidence that complex behaviors achieve lower levels of automaticity than simple behaviors (Lally, Van Jaarsveld, Potts, & Wardle,

2010; Verplanken, 2006; Wood, Quinn, & Kashy, 2002). In this light it has been suggested that a distinction between habitual deciding to perform a behavior (i.e. habitual instigation) and habitual performing that particular behavior (i.e. habitual execution) is meaningful (Gardner, 2015; Gardner et al., 2016; Phillips & Gardner, 2016). Take for instance running. A person who is very busy may carefully weigh every day whether going for a run fits in his agenda. This person has no instigation habit. Once running, however, this person may automatically follow the same trail, at the same intensity, thereby revealing the existence of an execution habit. In contrast, another person may never deliberate whether to go for a run, because contextual cues always prompt him automatically to go for a run. That person does have an instigation habit. However, if this person deliberately chooses to vary in trails, intensity, and duration at every run, this person does not have an execution habit. If going for a run is automatically prompted and the run is automatically enacted, then an instigation habit is combined with an execution habit. Whereas, to our knowledge, no study to date tested whether this distinction could be empirically observed for PA, one study on exercise did. That study found that habitual instigation, and not habitual execution, was a predictor of exercise frequency (Phillips & Gardner, 2016). Thus, the decision to start exercising is habitual, but the enactment is undertaken consciously and deliberately. This result shows that developing an instigation habit, but not necessarily encouraging adherence to an exercise routine, is important for establishing frequent exercise (Phillips & Gardner, 2016; see also Verplanken & Melkevik, 2008).

In the studies in this thesis three self-report measures were used to assess habit: the SRHI (Verplanken & Orbell, 2003), the SRBAI (Gardner et al., 2012b), and a measure consisting of four automaticity items that were taken from the eight item automaticity subscale of the SRHI. This latter habit measure and the SRBAI have two items in common. Although this measure resembles the SRBAI, a limitation is that it is not a validated instrument. The use of several SRHI-items to construct a nonvalidated habit scale occurs more often in habit research (see e.g. Fleig, Pomp, Parschau et al, 2013; Fleig, Pomp, Schwarzer et al., 2013; Honkanen, Olsen, & Verplanken, 2005; Olsen et al., 2013; Rhodes & De Bruijn, 2010). All three measures assess general habits and do not discern habitual instigation from habitual execution (Phillips & Gardner, 2016). However, the stem of the habit items from these measurement instruments can easily be adapted so that they target instigation or execution habits (Phillips & Gardner, 2016). The studies in this thesis used the stem 'Being sufficiently physically active is something…', which can be adapted to 'Deciding to do sufficient PA is something…' for instigation habits, and to 'Once performing sufficient PA, the act of performing sufficient PA is something…' for execution habits (cf. Gardner et al., 2016; Phillips & Gardner, 2016). The phrasing of the execution habit measure is rather complex. It is an empirical question whether this phrasing is too complex for low or

not educated respondents. Careful pilot testing is therefore recommended. Replication of the studies in this thesis using scales for instigation and execution habits instead of applying scales for general habits would provide insight into the usefulness of the distinction between instigation and execution habits for PA. Such replication research would help to further unravel the relationship between habit and PA.

PA not only is a complex kind of behavior because it consists of many subcomponents, but also because it is an aggregate behavior that is made up of many specific kinds of active behavior, such as exercise, commuting, gardening, and household activities. Does the same hold true for habits for being sufficiently physically active? It is most likely that habits for being sufficiently physically active do not exist as such, but are an aggregate of several habits for specific kinds of PA, such as habits for walking the dog, outdoor running, and taking the stairs. The advantage of operationalizing PA as the number of days that participants are sufficiently physically active according to public health guidelines (see Haskell et al., 2007; Nelson et al., 2007) is that it provides a standard to compare PA levels of the study population with. Participants can count the total number of minutes per day spent in various kinds of PA and decide on how many days per week they met the PA guideline. For habit, however, such simple arithmetic procedures cannot be applied, because participants can have strong habits for a particular aspect of PA, but weak habits for other aspects. Aggregate PA habit measures are thus to some extent compromises. These compromises may have attenuated the results of the current studies. The finding of the studies in this thesis that an aggregate measure of general habit nevertheless had significant relations to PA in longitudinal designs spanning one year, illustrates the mutual importance of habit and PA.

IMPLICATIONS FOR PRACTICE

Findings of this thesis provide intervention developers with two important insights. First, when developing PA promotion interventions for older adults based on the TPB/ASE model, existing habits have to be taken into account. If PA habits are low to medium, targeting intentions to increase PA may result in PA behavior change. Strong existing habits, on the other hand, limit the predictive power of intentions (see Chapter 2) and therefore the potential to change. In those who have strong PA habits, even if they are insufficiently physically active, persuasive messages that stimulate to increase PA intentionally often do not suffice to break these habits and translate intentions into action (Verplanken, Aarts, & Van Knippenberg, 1997). Opportunities to break or change strong habits for insufficient PA occur at significant life changes (i.e. life events) that disrupt existing habits by changing the performance environment (Verplanken & Wood,

2006). The absence of familiar habit cues forces people to make decisions about how to act; it provides a window of opportunity to implement new goals and intentions (Carden & Wood, 2018; Wood, Tam, & Guerrero Witt, 2005). For instance, consider an older adult living in an old people's home, wherein the elevator is located opposite the entrance. Due to the ease of taking the elevator, he might have taken the elevator so many times that is has become a habit. If this older adult moves to another old people's home wherein the stairs are located opposite the entrance and the elevator can only be reached by walking down a long corridor, he may consider climbing the stairs instead of taking the elevator and may eventually form a habit for climbing the stairs. The change in performance context (i.e. no elevator but stairs opposite the entrance) as a consequence of a life event (i.e. relocation) forced the older adult to make a conscious decision how to act (i.e. climbing the stairs instead of taking the elevator). Older adults generally face several life events (Seematter-Bagnoud, Karmaniola, & Santos-Eggimann, 2010), such as retirement, relocation, spouse caregiving, widowhood and other bereavements, and declining physical health (Wells, 2016). These life changing moments may be teachable moments as well. They provide promising contexts for interventions in older adults to change habits for insufficient PA and to form habits for sufficient PA (Verplanken & Wood, 2006). However, it must always be considered whether a life event truly provides an appropriate and acceptable context for PA interventions. For instance, people may reject invitations to participate in PA interventions immediately after entering widowhood, either because they have other things on their minds than PA, or because they consider the invitation to participate unacceptable during their period of grieve.

Second, PA was found to be the second last link in a chain of variables in which PA habit was the last link (see Chapter 4 and 5). The correlation between PA and subsequent PA habit was, however, not perfect, indicating that translation of PA into PA habits does not always occur and can be improved. Not forming PA habits entails the risk of relapses (Lally et al., 2008; Rothman et al., 2009; Verplanken & Wood, 2006). Indeed, a review of PA interventions in older adults found that they often result in short-lived behavior changes (Van der Bij, Laurant, & Wensing, 2002). Intervention strategies that support habit formation are thus needed. Consistency in pairing cues to behavior has been shown to foster habit formation (Kaushal & Rhodes, 2015; Lally et al., 2010). The use of reminders, self-monitoring, awareness of cues, and implementation intentions may also be effective in this regard (Lally & Gardner, 2013). Including habit formation strategies in PA interventions is strongly recommended.

DIRECTIONS FOR FUTURE RESEARCH

The present thesis can be considered a contribution to the disentanglement of the longitudinal relationship between habit and PA in older adults. This thesis found that habit plays three roles in its relation to PA. Habit is a moderator of the intention-PA relationship (Chapter 2), a mediator between prior and later PA (Chapter 3), and an outcome variable in habit-PA-habit (Chapter 4) and intention-PA-habit paths (Chapter 5). However, as the relationship between habit and PA and the construct of habit itself are not fully unraveled yet, several directions for future research are suggested below.

Replication studies are a crucial component of cumulative psychological science because they help establish the veracity of results through confirmation and disconfirmation (Brandt et al., 2014). Despite its importance relatively few replication studies are reported in psychological science (Makel, Plucker, & Hegarty, 2012). Replication of the studies in this thesis is recommended; close replications as well as replications with variations in study population, time intervals, and target behavior. Variations in target behavior can consist of specific kinds of PA, such as cycling or walking, as well as of PA behaviors with different goals, such as active commuting, leisure time PA, or exercise. It would also be worthwhile to use a broad operationalization of PA in line with the recently changed PA guideline in the Netherlands. This new guideline states that adults and older adults should engage in moderately intensive PA for at least 150 minutes per week, spread over several days, and should engage in PA that strengthens muscles and bones, at least twice a week (Health Council of the Netherlands, 2017). In addition, older adults should also perform balance exercises, at least twice a week (Health Council of the Netherlands, 2017). For replication studies, health-related behaviors other than PA can also serve as target behavior, since habit is not only important for PA, but also for other health-related behaviors, such as excessive alcohol consumption (Gardner, De Bruijn, & Lally, 2012; Norman, 2011), fruit consumption (De Bruijn, Keer, Conner, & Rhodes, 2012; Guillaumie, Godin, & Vézina-Im, 2010), condom use (Štulhofer, Baćak, Ajduković, & Graham, 2010; Trafimow, 2000), and dental flossing (Hamilton et al., 2018; Judah, Gardner, & Aunger, 2013).

Although studies have been conducted that target PA habit formation (Kaushal, Rhodes, Spence, et al., 2017; Lally et al., 2010), the majority of interventions to stimulate and maintain PA do not explicitly target habit formation (Lally et al., 2008). Some intervention strategies for habit formation have been proposed, such as the use of reminders, self-monitoring, and implementation intentions (Lally & Gardner, 2013). However, these strategies have, to our knowledge, not been subjected to abundant, rigorous experimental tests in relation to habit formation, neither for PA habits, nor

for habits for other health-related behaviors. The extent to which they support habit formation is therefore largely undetermined. In other words, little is known about if and how proposed habit formation strategies support the translation of PA into PA habits. Experimental evidence of their efficacy is needed to make well-informed choices when designing PA habit formation interventions. What are the most effective habit formation strategies? Does the effectiveness depend on population characteristics or target behavior (e.g. broadly defined PA or specific kinds of PA)? Can habit formation strategies be combined to enhance effectiveness? Conducting experimental tests to find answers on such questions is a worthy avenue for future research.

Another relevant direction for future research concerns the process of habit formation. It has been found that this process shows a curve wherein gains in habit strength diminish over time until habit strength reaches a plateau (Lally et al., 2010). This curve was found for healthy eating, drinking, and exercise behaviors (Lally et al., 2010). It would be worthwhile to map the process of habit formation for PA and to test whether this process takes place within different time frames for different age groups. Do older adults form habits more or less easily than younger adults? Or is there no difference at all? Insight into the time frames of habit formation for different age groups is necessary to design interventions of long enough duration.

At last, future research should target habit's stability and development over time. Although habit is supposed to be a stable construct, there is only little empirical evidence available on this stability (Gardner, Sheals, Wardle, & McGowan, 2014). The stability characteristic of habit is essential for connecting habit to behavior maintenance. It would be worthwhile to examine the impact of small events, such as having the flu, recovering from a fall, or celebrating holidays, on the stability of habit strength. Testing whether habit truly is a stable construct over time would contribute to insight into habit's nature and would provide a definitive rationale for targeting habit formation in interventions.

GENERAL CONCLUSION

Together the studies in this thesis show that habit and PA are longitudinally connected with each other in several ways; there is continuous, reciprocal influence between habit and PA. PA is a complex and multifaceted behavior that most probably will never be completely understood. This thesis shows that when trying to explain, predict, influence, and maintain this highly complex behavior, habits have to be taken into account. The connections that are uncovered in this thesis may foster both new research and

intervention development. Forming strong habits for sufficient PA may be a desired outcome of PA interventions, as they are proposed to ensure long-term maintenance of sufficient PA, which in turn leads to obtaining many health benefits. To put it short, many health benefits can be obtained by the force of strong habits for sufficient PA.

CHAPTER 7

REFERENCES

A

Aarts, H., & Dijksterhuis, A. (2000). Habits as knowledge structures: automaticity in goal-directed behavior. *Journal of Personality and Social Psychology, 78*, 53-63. doi: 10.1037/0022-3514.78.1.53

Aarts, H., Verplanken, B., & Van Knippenberg, A. (1997). Habit and information use in travel mode choices. *Acta Psychologica, 96*, 1-14. doi: 10.1016/S0001-6918(97)00008-5

Aarts, H., Verplanken, B., & Van Knippenberg, A. (1998). Predicting behavior from actions in the past: repeated decision making or a matter of habit? *Journal of Applied Social Psychology, 28*, 1355-1374. doi: 10.1111/j.1559-1816.1998.tb01681.x

Abraham, C., & Sheeran, P. (2004). Deciding to exercise: the role of anticipated regret. *British Journal of Health Psychology, 9*, 269-278. doi: 10.1348/135910704773891096

Aguinis, H., & Stone-Romero, E.F. (1997). Methodological artifacts in moderated multiple regression and their effects on statistical power. *Journal of Applied Psychology, 82*, 192-206. doi: 10.1037/0021-9010.82.1.192

Ajzen, I. (1991). The theory of planned behavior. *Organizational Behavior and Human Decision Processes, 50*, 179-211. doi: 10.1016/0749-5978(91)90020-T

Ajzen, I. (2002). Residual effects of past on later behavior: habituation and reasoned action perspectives. *Personality and Social Psychology Review, 6*, 107-122. doi: 10.1207/S15327957PSPR0602_02

Ajzen, I. (2011a). Is attitude research incompatible with the compatibility principle? In R.M. Arkin (Ed.), *Most underappreciated. 50 Prominent social psychologists describe their most unloved work* (pp. 151-154). New York: Oxford University Press.

Ajzen, I. (2011b). The theory of planned behaviour: reactions and reflections. *Psychology & Health, 26*, 1113-1127. doi: 10.1080/08870446.2011.613995

Ajzen, I. (2015a). The theory of planned behaviour is alive and well, and not ready to retire: a commentary on Sniehotta, Presseau, and Araújo-Soares. *Health Psychology Review, 9*, 131-137. doi: 10.1080/17437199.2014.883474

Ajzen, I. (2015b). Theory of planned behavior. Frequently asked questions. Retrieved February 18, 2015, from http://people.umass.edu/aizen/faq.html

Ajzen, I., & Fishbein, M. (2000). Attitudes and the attitude-behavior relation: reasoned and automatic processes. *European Review of Social Psychology, 11*, 1-33. doi: 10.1080/14792779943000116

Albery, I.P., Collins, I., Moss, A.C., Frings, D., & Spada, M.M. (2015). Habit predicts in-the-moment alcohol consumption. *Addictive Behaviors, 41*, 78-80. doi: 10.1016/j.addbeh.2014.09.025

Allain, P., Nicoleau, S., Pinon, K., Etcharry-Bouyx, F., Barré, J., Berrut, G., Dubas, F., & Le Gall, D. (2005). Executive functioning in normal aging: a study of action planning using the Zoo Map Test. *Brain and Cognition, 57*, 4-7. doi: 10.1016/j.bandc.2004.08.011

Allan, J.L., Johnston, M., & Campbell, N. (2011). Missed by an inch or a mile? Predicting the size of intention-behaviour gap from measures of executive control. *Psychology & Health, 6*, 635-650. doi: 10.1080/08870441003681307

Allom, V., Mullan, B., Cowie, E., & Hamilton, K. (2016). Physical activity and transitioning to college: the importance of intentions and habits. *American Journal of Health Behavior, 40*, 280-290. doi: 10.5993/AJHB.40.2.13

Andre, D., & Wolf, D.L. (2007). Recent advances in free-living physical activity monitoring: a review. *Journal of Diabetes Science and Technology, 1*, 760-767. doi: 10.1177/193229680700100522

Antikainen, I., & Ellis, R. (2011). A RE-AIM evaluation of theory-based physical activity interventions. *Journal of Sport & Exercise Psychology, 33*, 198-214. doi: 10.1123/jsep.33.2.198

Arnautovska, U., Fleig, L., O'Callaghan, F., & Hamilton, K. (2017). A longitudinal investigation of older adults' physical activity: testing an integrated dual-process model. *Psychology & Health, 32*, 166-185. doi: 10.1080/08870446.2016.1250273

B

Bamberg, S., Ajzen, I., & Schmidt, P. (2003). Choice of travel mode in the theory of planned behavior: the roles of past behavior, habit, and reasoned action. *Basic and Applied Social Psychology, 25*, 175-187. doi: 10.1207/S15324834BASP2503_01

Bargh, J.A. (1994). The four horsemen of automaticity: awareness, intention, efficiency, and control in social cognition. In R.S. Wyer Jr. & T.K. Srull (Eds.), *Handbook of social cognition: vol. 1 basic processes* (pp. 1-40). Hillsdale: Lawrence Erlbaum Associates.

Baron, R.M., & Kenny, D.A. (1986). The moderator-mediator variable distinction in social psychological research: conceptual, strategic, and statistical considerations. *Journal of Personality and Social Psychology, 51*, 1173-1182. doi: 10.1037/0022-3514.51.6.1173

Bartholomew, L.K., Parcel, G.S., Kok, G., Gottlieb, N.H., & Fernández, M.E. (2011). *Planning health promotion programs. An Intervention Mapping approach (3rd Ed.)*. San Francisco: Jossey-Bass.

Bassett, D.R. Jr., Ainsworth, B.E., Swartz, A.M., Strath, S.J., O'Brien, W.L., & King, G.A. (2000). Validity of four motion sensors in measuring moderate intensity physical activity. *Medicine & Science in Sports & Exercise, 32 (Suppl.)*, S471-S480. doi: 10.1097/00005768-200009001-00006

Bauman, A.E. (2004). Updating the evidence that physical activity is good for health: an epidemiological review 2000-2003. *Journal of Science and Medicine in Sport, 7 (Suppl.)*, 6-19. doi: 10.1016/S1440-2440(04)80273-1

Bélanger-Gravel, A., Godin, G., & Amireault, S. (2013). A meta-analytic review of the effect of implementation intentions on physical activity. *Health Psychology Review, 7*, 23-54. doi: 10.1080/17437199.2011.560095

Berendsen, B.A.J., Hendriks, M.R.C., Meijer, K., Plasqui, G., Schaper, N.C., & Savelberg, H.H.C.M. (2014). Which activity monitor to use? Validity, reproducibility and user friendliness of three activity monitors. *BMC Public Health, 14:749*. doi: 10.1186/1471-2458-14-749

Bherer, L., Erickson, K.I., Liu-Ambrose, T. (2013). A review of the effects of physical activity and exercise on cognitive and brain functions in older adults. *Journal of Aging Research, 2013*, 1-8. doi: 10.1155/2013/657508

Bollen, K.A. (1989). *Structural equations with latent variables*. New York: Wiley.

Bolman, C., Arwert, T.G., & Völlink, T. (2011). Adherence to prophylactic asthma medication: habit strength and cognitions. *Heart & Lung, 40*, 63-75. doi: 10.1016/j.hrtlng.2010.02.003

Bozionelos, G., & Bennett, P. (1999). The theory of planned behaviour as predictor of exercise. The moderating influence of beliefs and personality variables. *Journal of Health Psychology, 4*, 517-529. doi: 10.1177/135910539900400406

Brandt, M.J., IJzerman, H., Dijksterhuis, A., Farach, F.J., Geller, J., Giner-Sorolla, R., Grange, J.A., Perugini, M., Spies, J.R., & Van 't Veer, A. (2014). The Replication Recipe: whats makes for a convincing replication? *Journal of Experimental Social Psychology, 50*, 217-224. doi: 10.1016/j.jesp.2013.10.005

Brickell, T.A., Chatzisarantis, N.L.D., & Pretty, G.M. (2006). Using past behaviour and spontaneous implementation intentions to enhance the utility of the theory of planned behaviour in predicting exercise. *British Journal of Health Psychology, 11*, 249-262. doi: 10.1348/135910705X52471

Brug, J., De Vet, E., De Nooijer, J., & Verplanken, B. (2006). Predicting fruit consumption: cognitions, intention, and habits. *Journal of Nutrition Education and Behavior, 38*, 73-81. doi: 10.1016/j.jneb.2005.11.027

Brug, J., Lechner, L., & De Vries, H. (1995). Psychosocial determinants of fruit and vegetable consumption. *Appetite, 25*, 285-296. doi: 10.1006/appe.1995.0062

Brug, J., Oenema, A., & Ferreira, I. (2005). Theory, evidence and Intervention Mapping to improve behavior nutrition and physical activity interventions. *International Journal of Behavioral Nutrition and Physical Activity, 2:2*. doi: 10.1186/1479-5868-2-2

Byrne, B.M. (2012). *Structural equation modeling with Mplus*. New York: Routledge.

C

Cacioppo, J.T., & Petty, R.E. (1984). The elaboration likelihood model of persuasion. *Advances in Consumer Research, 11*, 673-675.

Carden, L., & Wood, W. (2018). Habit formation and change. *Current Opinion in Behavioral Sciences, 20*, 117-122. doi: 10.1016/j.cobeha.2017.12.009

Carlisle, C. (2014). *On habit*. London: Routledge.

Carraro, N., & Gaudreau, P. (2013). Spontaneous and experimentally induced action planning and coping planning for physical activity: a meta-analysis. *Psychology of Sport and Exercise, 14*, 228-248. doi: 10.1016/j.psychsport.2012.10.004

Caudroit, J., Stephan, Y., & Le Scanff, C. (2011). Social cognitive determinants of physical activity among retired older individuals: an application of the health action process approach. *British Journal of Health Psychology, 16*, 404-417. doi: 10.1348/135910710X518324

Centraal Bureau voor de Statistiek (2010). Gezondheid, leefstijl, zorggebruik 2000-2009 [Health, lifestyle, and use of health care 2000-2009]. Retrieved October 11, 2011, from http://bit.ly/2rTZ4o6

Centraal Bureau voor de Statistiek (2016). Leefstijl en preventie: geslacht, leeftijd, persoonskenmerken [Lifestyle and prevention: sex, age, personal characteristics]. Retrieved October 5, 2016, from http://bit.ly/2twlqMW

Centraal Bureau voor de Statistiek (2017). Prognose bevolking: kerncijfers 2017-2060 [Population prognosis: key figures 2017-2060]. Retrieved February 15, 2018, from http://bit.ly/2HfrSuO

Chassin, L., Presson, C.C., Sherman, S.J., Seo, D-C., & Macy, J.T. (2010). Implicit and explicit attitudes predict smoking cessation: moderating effects of experienced failure to control smoking and plans to quit. *Psychology of Addictive Behaviors, 24*, 670-679. doi: 10.1037/a0021722

Chatzisarantis, N.L.D., & Hagger, M.S. (2007). Mindfulness and the intention-behavior relationship within the theory of planned behavior. *Personality and Social Psychology Bulletin, 33*, 663-676. doi: 10.1177/0146167206297401

Chodzko-Zajko, W.J., Proctor, D.N., Singh, M.A.F., Minson, C.T., Nigg, C.R., Salem, G.J., & Skinner, J.S. (2009). Exercise and physical activity for older adults. *Medicine & Science in Sports & Exercise, 41*, 1510-1530. doi: 10.1249/MSS.0b013e3181a0c95c

Chomsky, N. (1959). Reviews. Verbal behavior. By B.F. Skinner. *Language, 35*, 26–58. doi: 10.2307/411334

Chou, C-P., & Bentler, P.M. (1995). Estimates and tests in structural equation modeling. In R.H. Hoyle (Ed.), *Structural equation modeling. Concepts, issues, and applications* (pp. 37-55). Thousand Oaks: Sage Publications.

Christensen, K., Doblhammer, G., Rau, R., & Vaupel, J.W. (2009). Ageing populations: the challenges ahead. *Lancet, 374*, 1196-1208. doi: 10.1016/S0140-6736(09)61460-4

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences (2nd Ed.)*. Hillsdale: Lawrence Erlbaum Associates.

Cohen, J. (1992). A power primer. *Psychological Bulletin, 112*, 155-159. doi: 10.1037/0033-2909.112.1.155

Conner, M. (2015). Extending not retiring the theory of planned behaviour: a commentary on Sniehotta, Presseau and Araújo-Soares. *Health Psychology Review, 9*, 141-145. doi: 10.1080/17437199.2014.899060

Conner, M., & Armitage, C.J. (1998). Extending the theory of planned behavior: a review and avenues for further research. *Journal of Applied Social Psychology, 28*, 1429-1464. doi: 10.1111/j.1559-1816.1998.tb01685.x

Conner, M., & Norman, P. (2005). Predicting health behaviour: a social cognition approach. In M. Conner & P. Norman (Eds.), *Predicting health behaviour (2nd Ed.)* (pp. 1-27). Maidenhead: Open University Press.

Conner, M., & Sparks, P. (2005) Theory of planned behaviour and health behaviour. In M. Conner & P. Norman (Eds.), *Predicting health behaviour (2nd Ed.)* (pp. 170-222). Maidenhead: Open University Press.

Conner, M., Warren, R., Close, S., & Sparks, P. (1999). Alcohol consumption and the theory of planned behavior: an examination of the cognitive mediation of past behavior. *Journal of Applied Social Psychology, 29*, 1676-1704. doi: 10.1111/j.1559-1816.1999.tb02046.x

Conroy, D.E., Hyde, A.L., Doerksen, S.E., & Ribeiro, N.F. (2010). Implicit attitudes and explicit motivation prospectively predict physical activity. *Annals of Behavioral Medicine, 39*, 112-118. doi: 10.1007/s12160-010-9161-0

Conroy, D.E., Maher, J.P., Elavsky, S., Hyde, A.L., & Doerksen, S.E. (2013). Sedentary behavior as a daily process regulated by habits and intentions. *Health Psychology, 32*, 1149-1157. doi: 10.1037/a0031629

Cooke, R., & Sheeran, P. (2004). Moderation of cognition-intention and cognition-behaviour relations: a meta-analysis of properties of variables from the theory of planned behaviour. *British Journal of Social Psychology, 43*, 159-186. doi: 10.1348/0144666041501688

Crutzen, R., Viechtbauer, W., Spigt, M., & Kotz, D. (2015). Differential attrition in health behaviour change trials: a systematic review and meta-analysis. *Psychology & Health, 30*, 122-134. doi: 10.1080/08870446.2014.953526

Cruz-Jentoft, A.J., Landi, F., Schneider, S.M., Zúñiga, C., Arai, H., Boirie, Y., Chen, L-K., Fielding, R.A., Martin, F.C., Michel, J-P., Sieber, C., Stout, J.R., Studenski, S.A., Vellas, B., Woo, J., Zamboni, M., & Cederholm, T. (2014). Prevalence of and interventions for sarcopenia in ageing adults: a systematic review. Report of the International Sarcopenia Initiative (EWGSOP and IWGS). *Age and Ageing, 43*, 748-759. doi: 10.1093/ageing/afu115

D

Danner, U.N., Aarts, H., & De Vries, N.K. (2008). Habit vs. intention in the prediction of future behaviour: the role of frequency, context stability and mental accessibility of past behaviour. *British Journal of Social Psychology, 47*, 245-265. doi: 10.1348/014466607X230876

De Bruijn, G-J. (2010). Understanding college students' fruit consumption. Integrating habit strength in the theory of planned behaviour. *Appetite, 54*, 16-22. doi: 10.1016/j.appet.2009.08.007

De Bruijn, G-J., & Gardner, B. (2011). Active commuting and habit strength: an interactive and discriminant analyses approach. *American Journal of Health Promotion, 25*, e27-e36. doi: 10.4278/ajhp.090521-QUAN-170

De Bruijn, G-J., Gardner, B., Van Osch, L., & Sniehotta, F.F. (2014). Predicting automaticity in exercise behaviour: the role of perceived behavioural control, affect, intention, action planning, and behaviour. *International Journal of Behavioral Medicine, 21*, 767-774. doi: 10.1007/s12529-013-9348-4

De Bruijn, G-J., Keer, M., Conner, M., & Rhodes, R.E. (2012). Using implicit associations towards fruit consumption to understand fruit consumption behaviour and habit strength relationships. *Journal of Health Psychology, 17*, 479-489. doi: 10.1177/1359105311421049

De Bruijn, G-J., Kremers, S.P.J., De Vet, E., De Nooijer, J., Van Mechelen, W., & Brug, J. (2007). Does habit strength moderate the intention-behaviour relationship in the theory of planned behaviour? The case of fruit consumption. *Psychology & Health, 22*, 899-916. doi: 10.1080/14768320601176113

De Bruijn, G-J., Kremers, S.P.J., Singh, A., Van den Putte, B., & Van Mechelen, W. (2009). Adult active transportation. Adding habit strength to the theory of planned behavior. *American Journal of Preventive Medicine, 36*, 189-194. doi: 10.1016/j.amepre.2008.10.019

De Bruijn, G-J., Kroeze, W., Oenema, A., & Brug, J. (2008). Saturated fat consumption and the theory of planned behaviour: exploring additive and interactive effects of habit strength. *Appetite, 51*, 318-323. doi: 10.1016/j.appet.2008.03.012

De Bruijn, G-J., & Rhodes, R.E. (2011). Exploring exercise behavior, intention and habit strength relationships. *Scandinavian Journal of Medicine & Science in Sports, 21*, 482-491. doi: 10.1111/j.1600-0838.2009.01064.x

De Bruijn, G-J., Rhodes, R.E., & Van Osch, L. (2012). Does action planning moderate the intention-habit interaction in the exercise domain? A three-way interaction analysis investigation. *Journal of Behavioral Medicine, 35*, 509-519. doi: 10.1007/s10865-011-9380-2

De Vries, H. (2017). An integrated approach for understanding health behavior: the I-Change Model as an example. *Psychology and Behavioral Science International Journal, 2:555585*. doi: 10.19080/PBSIJ.2017.02.555585

De Vries, H., Backbier, E., Kok, G., & Dijkstra, M. (1995). The impact of social influences in the context of attitude, self-efficacy, intention, and previous behavior as predictors of smoking onset. *Journal of Applied Social Psychology, 25*, 237-257. doi: 10.1111/j.1559-1816.1995.tb01593.x

De Vries, H., Dijkstra, M., & Kuhlman, P. (1988). Self-efficacy: the third factor besides attitude and subjective norm as a predictor of behavioural intentions. *Health Education Research, 3*, 273-282. doi: 10.1093/her/3.3.273

De Vries, H., Mesters, I., Van de Steeg, H., & Honing, C. (2005). The general public's information needs and perceptions regarding hereditary cancer: an application of the Integrated Change Model. *Patient Education and Counseling, 56*, 154-165. doi: 10.1016/j.pec.2004.01.002

De Vries, H., & Mudde, A.N. (1998). Predicting stage transitions for smoking cessation applying the attitude-social influence-efficacy model. *Psychology & Health, 13*, 369-385. doi: 10.1080/08870449808406757

De Vries, H., Mudde, A., Leijs, I., Charlton, A., Vartiainen, E., Buijs, G., Clemente, M.P., Storm, H., Navarro, A.G., Nebot, M., Prins, T., & Kremers, S. (2003). The European Smoking prevention Framework Approach (EFSA): an example of integral prevention. *Health Education Research, 18*, 611-626. doi: 10.1093/her/cyg031

Denton, F.T., & Spencer, B.G. (2010). Chronic health conditions: changing prevalence in an aging population and some implications for the delivery of health care services. *Canadian Journal on Aging, 29*, 11-21. doi: 10.1017/S0714980809990390

Department of Health (2004). *At least five a week. Evidence on the impact of physical activity and its relationship to health*. London: Department of Health.

Ding, D., Lawson, K.D., Kolbe-Alexander, T.L., Finkelstein, E.A., Katzmarzyk, P.T., Van Mechelen, W., & Pratt, M. (2016). The economic burden of physical inactivity: a global analysis of major non-communicable diseases. *Lancet, 388*, 1311-1324. doi: 10.1016/S0140-6736(16)30383-X

Durstine, J.L., Gordon, B., Wang, Z., & Luo, X. (2013). Chronic disease and the link to physical activity. *Journal of Sport and Health Science, 2*, 3-11. doi: 10.1016/j.jshs.2012.07.009

E

Eagly, A.H., & Chaiken, S. (1993). *The psychology of attitudes*. Belmont: Wadsworth.

Ellis, E.M., Collins, R.L., Homish, G.G., Parks, K.A., & Kiviniemi, M.T. (2016). Perceived controllability of condom use shifts reliance on implicit versus explicit affect. *Health Psychology, 35*, 842-846. doi: 10.1037/hea0000336

Esliger, D.W., Copeland, J.L., Barnes, J.D., & Tremblay, M.S. (2005). Standardizing and optimizing the use of accelerometer data for free-living physical activity monitoring. *Journal of Physical Activity and Health, 3*, 366-383. doi: 10.1123/jpah.2.3.366

Evans, J.St.B.T. (2008). Dual-processing accounts of reasoning, judgment, and social cognition. *Annual Review of Psychology, 59*, 255-278. doi: 10.1146/annurev.psych.59.103006.093629

F

Fazio, R.H. (1990). Multiple processes by which attitudes guide behavior: the MODE model as an integrative framework. *Advances in Experimental Social Psychology, 23*, 75-109. doi: 10.1016/S0065-2601(08)60318-4

Feldsjoe, B., Neuhaus, M., Winkler, E., & Eakin, E. (2011). Systematic review of maintenance of behavior change following physical activity and dietary interventions. *Health Psychology, 30*, 99-109. doi: 10.1037/a0021974

Ferreira, G.M., Yücel, M., Dawson, A., Lorenzetti, V., & Fontenelle, L.F. (2017). Investigating the role of anticipatory reward and habit strength in obsessive-compulsive disorder. *CNS Spectrums, 22*, 295-304. doi: 10.1017/S1092852916000535

Fishbein, M., & Ajzen, I. (2010). *Predicting and changing behavior. The reasoned action approach*. New York: Psychology Press.

Fleig, L., McAllister, M.M., Chen, P., Iverson, J., Milne, K., McKay, H.A., Clemson, L., & Ashe, M.C. (2016). Health behaviour change theory meets falls prevention: feasibility of a habit-based balance and strength exercise intervention for older adults. *Psychology of Sport and Exercise, 22*, 114-122. doi: 10.1016/j.psychsport.2015.07.002

Fleig, L., Pomp, S., Parschau, L., Barz, M., Lange, D., Schwarzer, R., & Lippke, S. (2013). From intentions via planning and behavior to physical exercise habits. *Psychology of Sport and Exercise, 14*, 632-639. doi: 10.1016/j.psychsport.2013.03.006

Fleig, L., Pomp, S., Schwarzer, R., & Lippke, S. (2013). Promoting exercise maintenance: how interventions with booster sessions improve long-term rehabilitation outcomes. *Rehabilitation Psychology, 58*, 323-333. doi: 10.1037/a0033885

French, D.P., Olander, E.K., Chisholm, A., & McSharry, J. (2014). Which behaviour change techniques are most effective at increasing older adults' self-efficacy and physical activity behaviour? A systematic review. *Annals of Behavioral Medicine, 48*, 225-234. doi: 10.1007/s12160-014-9593-z

Friese, M., Hofmann, W., & Wänke, M. (2008). When impulses take over: moderated predictive validity of explicit and implicit attitude measures in predicting food choice and consumption behaviour. *British Journal of Social Psychology, 47*, 397-419. doi: 10.1348/014466607X241540

G

Galla, B.M., & Duckworth, A.L. (2015). More than resisting temptation: beneficial habits mediate the relationship between self-control and positive life outcomes. *Journal of Personality and Social Psychology, 109*, 508-525. doi: 10.1037/pspp0000026

Garber, C.E., Blissmer, B., Deschenes, M.R., Franklin, B.A., Lamonte, M.J., Lee, I-M., Nieman, D.C., & Swain, D.P. (2011). Quantity and quality of exercise for developing and maintaining cardiorespiratory, musculoskeletal, and neuromotor fitness in apparently healthy adults: guidance for prescribing exercise. *Medicine & Science in Sports & Exercise, 43*, 1334-1359. doi: 10.1249/MSS.0b013e318213fefb

Gardner, B. (2009). Modelling motivation and habit in stable travel mode contexts. *Transportation Research Part F, 12*, 68-76. doi: 10.1016/j.trf.2008.08.001

Gardner, B. (2012). Habit as automaticity, not frequency. *European Health Psychologist, 14*, 32-36. doi: 10.1037/e544772013-003

Gardner, B. (2015). A review and analysis of the use of 'habit' in understanding, predicting and influencing health-related behaviour. *Health Psychology Review, 9*, 277-295. doi: 10.1080/17437199.2013.876238

Gardner, B., Abraham, C., Lally, P., & De Bruijn, G-J. (2012a). 'The habitual use of the self-report habit index': a reply. *Annals of Behavioral Medicine, 43*, 141-142. doi: 10.1007/s12160-011-9317-6

Gardner, B., Abraham, C., Lally, P., & De Bruijn, G-J. (2012b). Towards parsimony in habit measurement: testing the convergent and predictive validity of an automaticity subscale of the self-report habit index. *International Journal of Behavioral Nutrition and Physical Activity, 9:102*. doi: 10.1186/1479-5868-9-102

Gardner, B., De Bruijn, G-J., & Lally, P. (2011). A systematic review and meta-analysis of applications of the self-report habit index to nutrition and physical activity behaviours. *Annals of Behavioral Medicine, 42*, 174-187. doi: 10.1007/s12160-011-9282-0

Gardner, B., De Bruijn, G-J., & Lally, P. (2012). Habit, identity, and repetitive action: a prospective study of binge-drinking in UK students. *British Journal of Health Psychology, 17*, 565-581. doi: 10.1111/j.2044-8287.2011.02056.x

Gardner, B., & Lally, P. (2013). Does intrinsic motivation strengthen physical activity habit? Modeling relationships between self-determination, past behaviour, and habit strength. *Journal of Behavioral Medicine, 36*, 488-497. doi: 10.1007/s10865-012-9442-0

Gardner, B., Phillips, L.A., & Judah, G. (2016). Habitual instigation and habitual execution: definition, measurement, and effects on behaviour frequency. *British Journal of Health Psychology, 21*, 613-630. doi: 10.1111/bjhp.12189

Gardner, B., Sheals, K., Wardle, J., & McGowan, L. (2014). Putting habit into practice, and practice into habit: a process evaluation and exploration of the acceptability of a habit-based dietary behaviour change intervention. *International Journal of Behavioral Nutrition and Physical Activity, 11:135*. doi: 10.1186/s12966-014-0135-7

Gibbons, F.X., Houlihan, A.E., & Gerrard, M. (2009). Reason and reaction: the utility of a dual-focus, dual-processing perspective on promotion and prevention of adolescent health risk behaviour. *British Journal of Health Psychology, 14*, 231-248. doi: 10.1348/135910708X376640

Gigerenzer, G. (2008). Why heuristics work. *Perspectives on Psychological Science, 3*, 20-29. doi: 10.1111/j.1745-6916.2008.00058.x

Glanz, K., & Bishop, D.B. (2010). The role of behavioral science theory in development and implementation of public health interventions. *Annual Review of Public Health, 31*, 399-418. doi: 10.1146/annurev.publhealth.012809.103604

Godin, G., & Kok, G. (1996). The theory of planned behavior: a review of its applications to health-related behaviors. *American Journal of Health Promotion, 11*, 87-98. doi: 10.4278/0890-1171-11.2.87

Godin, G., Valois, P., & Lepage, L. (1993). The pattern of influence of perceived behavioral control upon exercising behavior: an application of Ajzen's theory of planned behavior. *Journal of Behavioral Medicine, 16*, 81-102. doi: 10.1007/BF00844756

Gollwitzer, P.M. (1999). Implementation intentions. Strong effects of simple plans. *American Psychologist, 54*, 493-503. doi: 10.1037/0003-066X.54.7.493

Gollwitzer, P.M., & Sheeran, P. (2006). Implementation intentions and goal achievement: a meta-analysis of effects and processes. *Advances in Experimental Social Psychology, 38*, 69-119. doi: 10.1016/S0065-2601(06)38002-1

Guillaumie, L., Godin, G., & Vézina-Im, L-A. (2010). Psychosocial determinants of fruit and vegetable intake in adult population: a systematic review. *International Journal of Behavioral Nutrition and Physical Activity, 7:12*. doi: 10.1186/1479-5868-7-12

H

Hagger, M.S. (2016). Non-conscious processes and dual-process theories in health psychology. *Health Psychology Review, 10*, 375-380, doi: 10.1080/17437199.2016.1244647

Hagger, M.S., & Chatzisarantis, N.L.D. (2014). An integrated behavior change model for physical activity. *Exercise and Sport Sciences Reviews, 42*, 62-69. doi: 10.1249/JES.0000000000000008

Hagger, M.S., Chatzisarantis, N.L.D., & Biddle, S.J.H. (2002). A meta-analytic review of the theories of reasoned action and planned behavior in physical activity: predictive validity and the contribution of additional variables. *Journal of Sport & Exercise Psychology, 24*, 3-32. doi: 10.1123/jsep.24.1.3

Hagger, M.S., & Luszczynska, A. (2014). Implementation intention and action planning interventions in health contexts: state of the research and proposals for the way forward. *Applied Psychology: Health and Well-Being, 6*, 1-47. doi: 10.1111/aphw.12017

Hagger, M.S., Rebar, A.L., Mullan, B., Lipp, O.V., & Chatzisarantis, N.L.D. (2015). The subjective experience of habit captured by self-report indexes may lead to inaccuracies in the measurement of habitual action. *Health Psychology Review, 9*, 296-302. doi: 10.1080/17437199.2014.959728

Hagger, M.S., Trost, N., Keech, J.J., Chan, D.K.C., & Hamilton, K. (2017). Predicting sugar consumption: application of an integrated dual-process, dual-phase model. *Appetite, 116*, 147-156. doi: 10.1016/j.appet.2017.04.032

Hallal, P.C., Andersen, L.B., Bull, F.C., Guthold, R., Haskell, W., & Ekelund, U. (2012). Global physical activity levels: surveillance progress, pitfalls, and prospects. *Lancet, 380*, 247-257. doi: 10.1016/S0140-6736(12)60646-1

Hamer, M., Lavoie, K.L., & Bacon, S.L. (2014). Taking up physical activity in later life and healthy ageing: the English longitudinal study of ageing. *British Journal of Sports Medicine, 48*, 239-243. doi: 10.1136/bjsports-2013-092993

Hamilton, K., Orbell, S., Bonham, M., Kroon, J., & Schwarzer, R. (2018). Dental flossing and automaticity: a longitudinal moderated mediation analysis. *Psychology, Health & Medicine, 23*, 619-627. doi: 10.1080/13548506.2017.1381339

Haskell, W.L., Lee, I-M., Pate, R.R., Powell, K.E., Blair, S.N., Franklin, B.A., Macera, C.A., Heath, G.W., Thompson, P.D., & Bauman, A. (2007). Physical activity and public health. Updated recommendation for adults from the American College of Sports Medicine and the American Heart Association. *Circulation, 116*, 1081-1093. doi: 10.1161/CIRCULATIONAHA.107.185649

Hayes, A.F. (2013). *Introduction to mediation, moderation, and conditional process analysis*. New York: Guilford Press.

Health Council of the Netherlands (2017). *Physical activity guidelines 2017* (publication no. 2017/08e). The Hague: Health Council of the Netherlands.

Helmerhorst, H.J.F., Brage, S., Warren, J., Besson, H., & Ekelund, U. (2012). A systematic review of reliability and objective criterion-related validity of physical activity questionnaires. *International Journal of Behavioral Nutrition and Physical Activity, 9:103*. doi: 10.1186/1479-5868-9-103

Hendelman, D., Miller, K., Baggett, C., Debold, E., & Freedson, P. (2000). Validity of accelerometry for the assessment of moderate intensity physical activity in the field. *Medicine & Science in Sports & Exercise, 32 (Suppl.)*, S442-S449. doi: 10.1097/00005768-200009001-00002

Hofmann, W., Friese, M., & Wiers, R.W. (2008). Impulsive versus reflective influences on health behavior: a theoretical framework and empirical review. *Health Psychology Review, 2*, 111-137. doi: 10.1080/17437190802617668

Hofmann, W., Rauch, W., & Gawronski, B. (2007). And deplete us not into temptation: automatic attitudes, dietary restraint, and self-regulatory resources as determinants of eating behavior. *Journal of Experimental Social Psychology, 43*, 497-504. doi: 10.1016/j.jesp.2006.05.004

Hollands, G.J., Marteau, T.M., & Fletcher, P.C. (2016). Non-conscious processes in changing health-related behaviour: a conceptual analysis and framework. *Health Psychology Review, 10*, 381-394. doi: 10.1080/17437199.2015.1138093

Honkanen, P., Olsen, S.O., & Verplanken, B. (2005). Intention to consume seafood - the importance of habit. *Appetite, 45*, 161-168. doi: 10.1016/j.appet.2005.04.005

Hooper, D., Couglan, J., & Mullen, M.R. (2008). Structural equation modelling: guidelines for determining model fit. *Electronic Journal of Business Research Methods, 6*, 53-60.

Houben, K., & Wiers, R.W. (2009). Response inhibition moderates the relationship between implicit associations and drinking behavior. *Alcoholism: Clinical and Experimental Research, 33*, 626-633. doi: 10.1111/j.1530-0277.2008.00877.x

Hu, L., & Bentler, P.M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: conventional criteria versus new alternatives. *Structural Equation Modeling, 6*, 1-55. doi: 10.1080/10705519909540118

Hull, C.L. (1943). *Principles of behavior. An introduction to behavior theory*. New York: Appleton-Century-Crofts.

I

Iwai, N., Hisamichi, S., Hayakawa, N., Inaba, Y., Nagaoka, T., Sugimori, H., Seki, N., Sakata, K., Suzuki, K., Tamakoshi, A., Nakamura, Y., Yamamoto, A., Nishino, Y., Ogihara, A., Okamoto, N., Suzuki, H., Morioka, S., Ito, Y., Wakai, K., Ojima, T., Tanaka, H., Nose, T., & Ohno, Y. (2001). Validity and reliability of single-item questions about physical activity. *Journal of Epidemiology, 11*, 211-218. doi: 10.2188/jea.11.211

J

Jackson, A.W., Morrow, J.R. Jr., Bowles, H.R., FitzGerald, S.J., & Blair, S.N. (2007). Construct validity evidence for single-response items to estimate physical activity levels in large sample studies. *Research Quarterly for Exercise and Sport, 78*, 24-31. doi: 10.5641/193250307X1308 2490460265

Jackson, C., Smith, R.A., & Conner, M. (2003). Applying an extended version of the theory of planned behaviour to physical activity. *Journal of Sports Sciences, 21*, 119-133. doi: 10.1080/0264041031000070976

James, W. (1890). *The principles of psychology*. New York: Henry Holt and Company.

Ji, M.F., & Wood, W. (2007). Purchase and consumption habits: not necessarily what you intend. *Journal of Consumer Psychology, 17*, 261-276. doi: 10.1016/S1057-7408(07)70037-2

Jose, P.E. (2013). *Doing statistical mediation & moderation*. New York: Guilford Press.

Judah, G., Gardner, B., & Aunger, R. (2013). Forming a flossing habit: an exploratory study of the psychological determinants of habit formation. *British Journal of Health Psychology, 18*, 338-353. doi: 10.1111/j.2044-8287.2012.02086.x

K

Karlsson, M.K., Vonschewelov, T., Karlsson, C., Cöster, M., & Rosengen, B.E. (2013). Prevention of falls in the elderly: a review. *Scandinavian Journal of Public Health, 41*, 442-454. doi: 10.1177/1403494813483215

Kaushal, N., & Rhodes, R.E. (2015). Exercise habit formation in new gym members: a longitudinal study. *Journal of Behavioral Medicine, 38*, 652-663. doi: 10.1007/s10865-015-9640-7

Kaushal, N., Rhodes, R.E., Meldrum, J.T., & Spence, J.C. (2017). The role of habit in different phases of exercise. *British Journal of Health Psychology, 22*, 429-448. doi: 10.1111/bjhp.12237

Kaushal, N., Rhodes, R.E., Spence, J.C., & Meldrum, J.T. (2017). Increasing physical activity through principles of habit formation in new gym members: a randomized controlled trial. *Annals of Behavioral Medicine, 51*, 578-586. doi: 10.1007/s12160-017-9881-5

Keatley, D., Clarke, D.D., & Hagger, M.S. (2012). Investigating the predictive validity of implicit and explicit measures of motivation on condom use, physical activity and healthy eating. *Psychology & Health, 27*, 550-569. doi: 10.1080/08870446.2011.605451

Kemper, H.C.G., Ooijendijk, W.T.M., & Stiggelbout, M. (2000). Consensus over de Nederlandse norm voor gezond bewegen [Consensus about the Dutch physical activity guideline]. *Tijdschrift voor Sociale Geneeskunde, 78*, 180-183.

Kenny, D.A. (2011). Moderation. Retrieved May 10, 2012, from http://davidakenny.net/cm/moderation.htm

King, A.C. (2001). Interventions to promote physical activity by older adults. *Journal of Gerontology: Series A, 56 (Suppl.2)*, 36-46. doi: 10.1093/gerona/56.suppl_2.36

Kline, R.B. (2011). *Principles and practice of structural equation modeling*. New York: Guilford Press.

Knuth, A.G., & Hallal, P.C. (2009). Temporal trends in physical activity: a systematic review. *Journal of Physical Activity and Health, 6*, 548-559. doi: 10.1123/jpah.6.5.548

Kor, K., & Mullan, B.A. (2011). Sleep hygiene behaviours: an application of the theory of planned behaviour and the investigation of perceived autonomy support, past behaviour and response inhibition. *Psychology & Health, 26*, 1208-1224. doi: 10.1080/08870446.2010.551210

Kremers, S.P.J., & Brug, J. (2008). Habit strength of physical activity and sedentary behavior among children and adolescents. *Pediatric Exercise Science, 20*, 5-17. doi: 10.1123/pes.20.1.5

Kremers, S.P.J., De Bruijn, G-J., Visscher, T.L.S., Van Mechelen, W., De Vries, N.K., & Brug, J. (2006). Environmental influences on energy balance-related behaviors: a dual-process view. *International Journal of Behavioral Nutrition and Physical Activity, 3:9*. doi: 10.1186/1479-5868-3-9

Krishna, A., & Strack, F. (2017). Reflection and impulse as determinants of human behavior. In P. Meusburger, B. Werlen, & L. Suarsana (Eds.), *Knowledge and action* (pp. 145-167). Cham: Springer.

Kurz, T., Gardner, B., Verplanken, B., & Abraham, C. (2015). Habitual behaviors or patterns of practice? Explaining and changing repetitive climate-relevant actions. *WIREs Climate Change, 6*, 113-128. doi: 10.1002/wcc.327

L

Labrecque, J.S., & Wood, W. (2015). What measures of habit strength to use? Comment on Gardner (2015). *Health Psychology Review, 9*, 303-310. doi: 10.1080/17437199.2014.992030

Lally, P., Chipperfield, A., & Wardle, J. (2008). Healthy habits: efficacy of simple advice on weight control based on a habit-formation model. *International Journal of Obesity, 32*, 700-707. doi: 10.1038/sj.ijo.0803771

Lally, P., & Gardner, B. (2013). Promoting habit formation. *Health Psychology Review, 7 (Suppl.1)*, S137-S158. doi: 10.1080/17437199.2011.603640

Lally, P., Van Jaarsveld, C.H.M., Potts, H.W.W., & Wardle, J. (2010). How habits are formed: modelling habit formation in the real world. *European Journal of Social Psychology, 40*, 998-1009. doi: 10.1002/ejsp.674

Lally, P., Wardle, J., & Gardner, B. (2011). Experiences of habit formation: a qualitative study. *Psychology, Health & Medicine, 16*, 484-489. doi: 10.1080/13548506.2011.555774

Landis, R.S., Edwards, B.D., & Cortina, J.M. (2009). On the practice of allowing correlated residuals among indicators in structural equation models. In C.E. Lance & R.J. Vandenberg (Eds.), *Statistical and methodological myths and urban legends: doctrine, verity and fable in organizational and social sciences* (pp. 193-215). New York: Routledge.

Lechner, L., De Nooijer, J., & De Vries, H. (2004). Breast self-examination: longitudinal predictors of intention and subsequent behaviour. *European Journal of Cancer Prevention, 13*, 369–376. doi: 10.1097/00008469-200410000-00003

Lechner, L., & De Vries, H. (1995). Participation in an employee fitness program: determinants of high adherence, low adherence, and dropout. *Journal of Occupational and Environmental Medicine, 37*, 429-436. doi: 10.1097/00043764-199504000-00014

Lee, I-M., & Shiroma, E.J. (2014). Using accelerometers to measure physical activity in large-scale epidemiological studies: issues and challenges. *British Journal of Sports Medicine, 48*, 197-201. doi: 10.1136/bjsports-2013-093154

Lee, I-M., Shiroma, E.J., Lobelo, F., Puska, P., Blair, S.N., & Katzmarzyk, P.T. (2012). Effect of physical inactivity on major non-communicable diseases worldwide: an analysis of burden of disease and life expectancy. *Lancet, 380*, 219-229. doi: 10.1016/S0140-6736(12)61031-9

Lee, W-K. (2014). The temporal relationships among habit, intention and IS uses. *Computers in Human Behavior, 32*, 54-60. doi: 10.1016/j.chb.2013.11.010

Levy, B.R., Ashman, O., & Slade, M.D. (2009). Age attributions and aging health: contrast between the United States and Japan. *Journal of Gerontology: Series B: Psychological Sciences and Social Sciences, 64*, 335-338. doi: 10.1093/geronb/gbp002

Li, S., Carlson, E., & Holm, K. (2000). Validation of a single-item measure of usual physical activity. *Perceptual and Motor Skills, 91*, 593-602. doi: 10.2466/pms.2000.91.2.593

Lippke, S., Ziegelmann, J.P., & Schwarzer, R. (2004). Behavioral intentions and action plans promote physical exercise: a longitudinal study with orthopedic rehabilitation patients. *Journal of Sport & Exercise Psychology, 26*, 470-483. doi: 10.1123/jsep.26.3.470

Lleras, C. (2005). Path analysis. *Encyclopedia of Social Measurement, 3*, 25-30. doi: 10.1016/B0-12-369398-5/00483-7

M

MacKinnon, D.P. (2008). *Introduction to statistical mediation analysis*. New York: Lawrence Erlbaum Associates.

MacKinnon, D.P., Warsi, G., & Dwyer, J.H. (1995). A simulation study of mediated effect measures. *Multivariate Behavioral Research, 30*, 41-62. doi: 10.1207/s15327906mbr3001_3

Maher, J.P., & Conroy, D.E. (2016). A dual-process model of older adults' sedentary behavior. *Health Psychology, 35*, 262-272. doi: 10.1037/hea0000300

Makel, M.C., Plucker, J.A., & Hegarty, B. (2012). Replications in psychology research: how often do they really occur? *Perspectives on Psychological Science, 7*, 537-542. doi: 10.1177/1745691612460688

Marteau, T.M., Hollands, G.J., & Fletcher, P.C. (2012). Changing human behavior to prevent disease: the importance of targeting automatic processes. *Science, 337*, 1492-1495. doi: 10.1126/science.1226918

McEachan, R.R.C., Conner, M., Taylor, N.J., & Lawton, R.J. (2011). Prospective prediction of health-related behaviours with the theory of planned behaviour: a meta-analysis. *Health Psychology Review, 5*, 97-144. doi: 10.1080/17437199.2010.521684

McKee, G., Kearney, P.M., & Kenny, R.A. (2015). The factors associated with self-reported physical activity in older adults living in the community. *Age and Ageing, 44*, 586-592. doi: 10.1093/ageing/afv042

Michie, S., & Johnston, M. (2012). Theories and techniques of behaviour change: developing a cumulative science of behaviour change. *Health Psychology Review, 6*, 1-6. doi: 10.1080/17437199.2012.654964

Michie, S., West, R., Campbell, R., Brown, J., & Gainforth, H. (2014). *ABC of behaviour change theories*. London: Silverback Publishing.

Milton, K., Bull, F.C., & Bauman, A. (2011). Reliability and validity testing of a single-item physical activity measure. *British Journal of Sports Medicine, 45*, 203-208. doi: 10.1136/bjsm.2009.068395

Milton, K., Clemes, S., & Bull, F. (2013). Can a single question provide an accurate measure of physical activity? *British Journal of Sports Medicine, 47*, 44-48. doi: 10.1136/bjsports-2011-090899

Motl, R.W., & McAuley, E. (2010). Physical activity, disability, and quality of life in older adults. *Physical Medicine and Rehabilitation Clinics of North America, 21*, 299-308. doi: 10.1016/j.pmr.2009.12.006

Murphy, S.L. (2009). Review of physical activity measurement using accelerometers in older adults: considerations for research design and conduct. *Preventive Medicine, 48*, 108-114. doi: 10.1016/j.ypmed.2008.12.001

Muthén, L.K., & Muthén, B.O. (1998-2007). *Mplus user's guide (5th Ed.)*. Los Angeles: Muthén & Muthén.

N

National Institute on Aging & World Health Organization (2011). *Global health and aging*. (NIH Publication no. 11-7737). Retrieved April 12, 2017, from http://bit.ly/2rCxBCS

Naughton, P., McCarthy, M., & McCarthy, S. (2015). Acting to self-regulate unhealthy eating habits. An investigation into the effects of habit, hedonic hunger and self-regulation on sugar consumption from confectionery foods. *Food Quality and Preference, 46*, 173-183. doi: 10.1016/j.foodqual.2015.08.001

Ndahimana, D., & Kim, E-K. (2017). Measurement methods for physical activity and energy expenditure: a review. *Clinical Nutrition Research, 6*, 68-80. doi: 10.7762/cnr.2017.6.2.68

Neal, D.T., Wood, W., & Drolet, A. (2013). How do people adhere to goals when willpower is low? The profits (and pitfalls) of strong habits. *Journal of Personality and Social Psychology, 104*, 959-975. doi: 10.1037/a0032626

Neal, D.T., Wood, W., Labrecque, J.S., & Lally, P. (2012). How do habits guide behavior? Perceived and actual triggers of habits in daily life. *Journal of Experimental Social Psychology, 48*, 492-498. doi: 10.1016/j.jesp.2011.10.011

Nelson, M.E., Rejeski, W.J., Blair, S.N., Duncan, P.W., Judge, J.O., King, A.C., Macera, C.A., & Castaneda-Sceppa, C. (2007). Physical activity and public health in older adults: recommendation from the American College of Sports Medicine and the American Heart Association. *Medicine & Science in Sports & Exercise, 39*, 1435-1445. doi: 10.1249/mss.0b013e3180616aa2

Norman, P. (2011). The theory of planned behavior and binge drinking among undergraduate students: assessing the impact of habit strength. *Addictive Behaviors, 36*, 502-507. doi: 10.1016/j.addbeh.2011.01.025

Norman, P., & Smith, L. (1995). The theory of planned behaviour and exercise: an investigation into the role of prior behaviour, behavioural intentions and attitude variability. *European Journal of Social Psychology, 25*, 403-415. doi: 10.1002/ejsp.2420250405

Notthoff, N., Reisch, P., & Gerstorf, D. (2017). Individual characteristics and physical activity in older adults: a systematic review. *Gerontology, 63*, 443-459. doi: 10.1159/000475558

O

Olsen, C.L. (1976). On choosing a test statistic in multivariate analysis of variance. *Psychological Bulletin, 83*, 579-586. doi: 10.1037/0033-2909.83.4.579

Olsen, S.O., Tudoran, A.A., Brunsø, K., & Verbeke, W. (2013). Extending the prevalent consumer loyalty modelling: the role of habit strength. *European Journal of Marketing, 47*, 303-323. doi: 10.1108/03090561311285565

Orbell, S., & Verplanken, B. (2010). The automatic component of habit in health behavior: habit as cue-contingent automaticity. *Health Psychology, 29*, 374-383. doi: 10.1037/a0019596

Orbell, S., & Verplanken, B. (2015). The strength of habit. *Health Psychology Review, 9*, 311-317. doi: 10.1080/17437199.2014.992031

Ouellette, J.A., & Wood, W. (1998). Habit and intention in everyday life: the multiple processes by which past behavior predicts future behavior. *Psychological Bulletin, 124*, 54-74. doi: 10.1037/0033-2909.124.1.54

P

Pahor, M., Guralnik, J.M., Ambrosius, W.T., Blair, S., Bonds, D.E., Church, T.S., Espeland, M.A., Fielding, R.A., Gill, T.M., Groessl, E.J., King, A.C., Kritchevsky, S.B., Manini, T.M., McDermott, M.M., Miller, M.E., Newman, A.B., Rejeski, J., Sink, K.M., & Williamson, J.D. (2014). Effect of structured physical activity on prevention of major mobility disability in older adults. The LIFE Study randomized clinical trial. *JAMA, 311*, 2387-2396. doi: 10.1001/jama.2014.5616

Papies, E.K. (2016). Health goal priming as a situated intervention tool: how to benefit from nonconscious motivational routes to health behaviour. *Health Psychology Review, 10*, 408-424. doi: 10.1080/17437199.2016.1183506

Park, D.C. (1999). Aging and the controlled and automatic processing of medical information and medical intentions. In D.C. Park, R.W. Morrell & K. Shifren (Eds.), *Processing of medical information in aging patients: cognitive and human factors perspectives* (pp. 3-22). Mahwah: Lawrence Erlbaum Associates.

Parrott, M.W., Tennant, L.K., Olejnik, S., & Poudevigne, M.S. (2008). Theory of planned behavior: implications for an email-based physical activity intervention. *Psychology of Sport and Exercise, 9*, 511-526. doi: 10.1016/j.psychsport.2007.07.002

Paterson, D.H., & Warburton, D.E.R. (2010). Physical activity and functional limitations in older adults: a systematic review related to Canada's physical activity guidelines. *International Journal of Behavioral Nutrition and Physical Activity, 7:38*. doi: 10.1186/1479-5868-7-38

Peels, D.A. (2014). *Promoting physical activity of people aged over fifty. Feasibility and (cost-) effectiveness of the web-based versus the print-delivered computer-tailored active plus intervention.* Unpublished doctoral dissertation, Open Universiteit Nederland, Heerlen.

Peels, D.A., Bolman, C., Golsteijn, R.H.J., De Vries, H., Mudde, A.N., Van Stralen, M.M., & Lechner, L. (2012). Differences in reach and attrition between web-based and print-delivered tailored interventions among adults over 50 years of age: clustered randomized trial. *Journal of Medical Internet Research, 14:e179*. doi: 10.2196/jmir.2229

Peels, D.A., Bolman, C., Golsteijn, R.H.J., De Vries, H., Mudde, A.N., Van Stralen, M.M., & Lechner, L. (2013). Long-term efficacy of a printed or a web-based tailored physical activity intervention among older adults. *International Journal of Behavioral Nutrition and Physical Activity, 10:104*. doi: 10.1186/1479-5868-10-104

Peels, D.A., Hoogenveen, R.R., Feenstra, T.L., Golsteijn, R.H.J., Bolman, C., Mudde, A.N., Wendel-Vos, G.C.W., De Vries, H., & Lechner, L. (2014). Long-term health outcomes and cost-effectiveness of a computer-tailored physical activity intervention among people aged over fifty: modelling the results of a randomized controlled trial. *BMC Public Health, 14:1099*. doi: 10.1186/1471-2458-14-1099

Pettee, K.K., Storti, K.L., Ainsworth, B.E., & Kriska, A.M. (2009). Measurement of physical activity and inactivity in epidemiologic studies. In I-M. Lee (Ed.), *Epidemiologic methods in physical activity studies* (pp. 15-33). New York: Oxford University Press.

Peyrot, M. (1996). Causal analysis: theory and application. *Journal of Pediatric Psychology, 21*, 3-24. doi: 10.1093/jpepsy/21.1.3

Phillips, L.A., & Gardner, B. (2016). Habitual exercise instigation (vs. execution) predicts healthy adults' exercise frequency. *Health Psychology, 35*, 69-77. doi: 10.1037/hea0000249

Preacher, K.J., & Kelley, K. (2011). Effect size measures for mediation models: quantitative strategies for communicating indirect effects. *Psychological Methods, 16*, 93-115. doi: 10.1037/a0022658

Prince, S.A., Adamo, K.B., Hamel, M.E., Hardt, J., Gorber, S.C., & Tremblay, M. (2008). A comparison of direct versus self-report measures for assessing physical activity in adults: a systematic review. *International Journal of Behavioral Nutrition and Physical Activity, 5:56*. doi: 10.1186/1479-5868-5-56

Q

Quinn, J.M., Pascoe, A., Wood, W., & Neal, D.T. (2010). Can't control yourself? Monitor those bad habits. *Personality and Social Psychology Bulletin, 36*, 499-511. doi: 10.1177/0146167209360665

Quinton, T.St., & Brunton, J.A. (2017). Implicit processes, self-regulation, and interventions for behavior change. *Frontiers in Psychology, 8:346*. doi: 10.3389/fpsyg.2017.00346

R

Rebar, A.L., Dimmock, J.A., Jackson, B., Rhodes, R.E., Kates, A., Starling, J., & Vandelanotte, C. (2016). A systematic review of the effects of non-conscious regulatory processes in physical activity. *Health Psychology Review, 10*, 395-407. doi: 10.1080/17437199.2016.1183505

Rebar, A.L., Elavsky, S., Maher, J.P., Doerksen, S.E., & Conroy, D.E. (2014). Habits predict physical activity on days when intentions are weak. *Journal of Sport & Exercise Psychology, 36*, 157-165. doi: 10.1123/jsep.2013-0173

Reinaerts, E., De Nooijer, J., Candel, M., & De Vries, N. (2007). Explaining school children's fruit and vegetable consumption: the contributions of availability, accessibility, exposure, parental consumption and habit in addition to psychosocial factors. *Appetite, 48*, 248-258. doi: 10.1016/j.appet.2006.09.007

Reiner, M., Niermann, C., Jekauc, D., & Woll, A. (2013). Long-term health benefits of physical activity - a systematic review of longitudinal studies. *BMC Public Health, 13:813*. doi: 10.1186/1471-2458-13-813

Rejeski, W.J., & Mihalko, S.L. (2001). Physical activity and quality of life in older adults. *Journals of Gerontology: Series A: Biological Sciences and Medical Sciences, 56 (Suppl.2)*, 23-35. doi: 10.1093/gerona/56.suppl_2.23

Resnick, B., & Jenkins, L.S. (2000). Testing the reliability and validity of the self-efficacy for exercise scale. *Nursing Research, 49*, 154-159. doi: 10.1097/00006199-200005000-00007

Rhodes, R., De Bruijn, G-J., & Matheson, D.H. (2010). Habit in the physical activity domain: integration with intention temporal stability and action control. *Journal of Sport & Exercise Psychology, 32*, 84-98. doi: 10.1123/jsep.32.1.84

Rhodes, R.E., & De Bruijn, G-J. (2010). Automatic and motivational correlates of physical activity: does intensity moderate the relationship? *Behavioral Medicine, 36*, 44-52. doi: 10.1080/08964281003774901

Rhodes, R.E., & Dickau, L. (2012). Experimental evidence for the intention-behavior relationship in the physical activity domain: a meta-analysis. *Health Psychology, 31*, 724-727. doi: 10.1037/a0027290

Rhodes, R.E., & Dickau, L. (2013). Moderators of the intention-behaviour relationship in the physical activity domain: a systematic review. *British Journal of Sports Medicine, 47*, 215-225. doi: 10.1136/bjsports-2011-090411

Rhodes, R.E., Janssen, I., Bredin, S.S.D., Warburton, D.E.R., & Bauman, A. (2017). Physical activity: health impact, prevalence, correlates and interventions. *Psychology & Health, 32*, 942-975. doi: 10.1080/08870446.2017.1325486

Rhodes, R.E., & Yao, C.A. (2015). Models accounting for intention-behavior discordance in the physical activity domain: a user's guide, content overview, and review of current evidence. *International Journal of Behavioral Nutrition and Physical Activity, 12:9*. doi: 10.1186/s12966-015-0168-6

Rijksinstituut voor Volksgezondheid en Milieu (2014). *Een gezonder Nederland. Kernboodschappen van de Volksgezondheid Toekomst Verkenning 2014 [The Netherlands healthier. Core messages from the National Health Future Explorations 2014]*. Bilthoven: Rijksinstituut voor Volksgezondheid en Milieu.

Rothman, A.J., Sheeran, P., & Wood, W. (2009). Reflective and automatic processes in the initiation and maintenance of dietary change. *Annals of Behavioral Medicine, 38 (Suppl.1)*, S4-S17. doi: 10.1007/s12160-009-9118-3

Rubenstein, L.Z. (2006). Falls in older people: epidemiology, risk factors and strategies for prevention. *Age and Ageing, 35 (Suppl.2)*, ii37-ii41. doi: 10.1093/ageing/afl084

S

Sallis, J.F., Bull, F., Guthold, R., Heath, G.W., Inoue, S., Kelly, P., Oyeyemi, A.L., Perez, L.G., Richards, J., & Hallal, P.C. (2016). Progress in physical activity over the Olympic quadrennium. *Lancet, 388*, 1325-1336. doi: 10.1016/s0140-6736(16)30581-5

Sarafino, E.P., & Smith, T.W. (2014). *Health psychology: biopsychosocial interactions (8th Ed.)*. New York: Wiley.

Sarkisian, C.A., Liu, H., Ensrud, K.E., Stone, K.L., & Mangione, C.M. (2001). Correlates of attributing new disability to old age. *Journal of the American Geriatrics Society, 49*, 134-141. doi: 10.1046/j.1532-5415.2001.49033.x

Scholz, U., Schüz, B., Ziegelmann, J.P., Lippke, S., & Schwarzer, R. (2008). Beyond behavioural intentions: planning mediates between intentions and physical activity. *British Journal of Health Psychology, 13*, 479-494. doi: 10.1348/135910707X216062

Schneider, W., & Shiffrin, R.M. (1977). Controlled and automatic human information processing: I. Detection, search, and attention. *Psychological Review, 84*, 1-66. doi: 10.1037/0033-295X.84.1.1

Schumacker, R.E., & Lomax, R.G. (2010). *A beginner's guide to structural equation modeling (3rd Ed.)*. New York: Routledge.

Schwarzer, R. (2008). Modeling health behavior change: how to predict and modify the adoption and maintenance of health behaviors. *Applied Psychology, 57*, 1-29. doi: 10.1111/j.1464-0597.2007.00325.x

Schwarzer, R. (2015). Some retirees remain active: a commentary on Sniehotta, Presseau and Araújo-Soares. *Health Psychology Review, 9*, 138-140. doi: 10.1080/17437199.2014.898407

Scollon, C.N., Kim-Prieto, C., & Diener, E. (2003). Experience sampling: promises and pitfalls, strengths and weaknesses. *Journal of Happiness Studies, 4*, 5-34. doi: 10.1023/A:1023605205115

Seco, J., Abecia, L.C., Echevarría, E., Barbero, I., Torres-Unda, J., Rodriguez, V., & Calvo, J.I. (2013). A long-term physical activity training program increases strength and flexibility, and improves balance in older adults. *Rehabilitation Nursing, 38*, 37-47. doi: 10.1002/rnj.64

Seematter-Bagnoud, L., Karmaniola, A., & Santos-Eggimann, B. (2010). Adverse life events among community-dwelling persons aged 65-70 years: gender differences in occurrence and perceived psychological consequences. *Social Psychiatry and Psychiatric Epidemiology, 45*, 9-16. doi: 10.1007/s00127-009-0035-3

Sheeran, P. (2002). Intention-behavior relations: a conceptual and empirical review. *European Review of Social Psychology, 12*, 1-36. doi: 10.1080/14792772143000003

Sheeran, P., Gollwitzer, P.M., & Bargh, J.A. (2013). Nonconscious processes and health. *Health Psychology, 32*, 460-473. doi: 10.1037/a0029203

Sheeran, P., & Orbell, S. (1999). Implementation intentions and repeated behaviour: augmenting the predictive validity of the theory of planned behaviour. *European Journal of Social Psychology, 29*, 349-369. doi: 10.1002/(SICI)1099-0992(199903/05)29:2/3<349::AID-EJSP931>3.0.CO;2-Y

Sherrington, C., Tiedemann, A., Fairhall, N., Close, J.C.T., & Lord, S.R. (2011). Exercise to prevent falls in older adults: an updated meta-analysis and best practice recommendations. *New South Wales Public Health Bulletin, 22*, 78-83. doi: 10.1071/NB10056

Shiffrin, R.M., & Schneider, W. (1977). Controlled and automatic human information processing: II. Perceptual learning, automatic attending, and a general theory. *Psychological Review, 84*, 127-190. doi: 10.1037/0033-295X.84.2.127

Skinner, B.F. (1938). *The behavior of organisms. An experimental analysis*. New York: Appleton-Century-Crofts.

Smith, J.R., Terry, D.J., Manstead, A.S.R., Louis, W.R., Kotterman, D., & Wolfs, J. (2007). Interaction effects in the theory of planned behavior: the interplay of self-identity and past behavior. *Journal of Applied Social Psychology, 37*, 2726-2750. doi: 10.1111/j.1559-1816.2007.00278.x

Smyth, J.M., & Stone, A.A. (2003). Ecological momentary assessment research in behavioural medicine. *Journal of Happiness Studies, 4*, 35-52. doi: 10.1023/A:1023657221954

Sniehotta, F.F. (2009). Towards a theory of intentional behaviour change: plans, planning, and self-regulation. *British Journal of Health Psychology, 14*, 261-273. doi: 10.1348/135910708X389042

Sniehotta, F.F., & Presseau, J. (2012). The habitual use of the self-report habit index. *Annals of Behavioral Medicine, 43*, 139-140. doi: 10.1007/s12160-011-9305-x

Sniehotta, F.F., Presseau, J., & Araújo-Soares, V. (2014). Time to retire the theory of planned behaviour. *Health Psychology Review, 8*, 1-7. doi: 10.1080/17437199.2013.869710

Sniehotta, F.F., Scholz, U., & Schwarzer, R. (2005). Bridging the intention-behaviour gap: planning, self-efficacy, and action control in the adoption and maintenance of physical exercise. *Psychology & Health, 20*, 143-160. doi: 10.1080/08870440512331317670

Sniehotta, F.F., Scholz, U., & Schwarzer, R. (2006). Action plans and coping plans for physical exercise: a longitudinal intervention study in cardiac rehabilitation. *British Journal of Health Psychology, 11*, 23-37. doi: 10.1348/135910705X43804

Sniehotta, F.F., Schwarzer, R., Scholz, U., & Schüz, B. (2005). Action planning and coping planning for long-term lifestyle change: theory and assessment. *European Journal of Social Psychology, 35*, 565-576. doi: 10.1002/ejsp.258

Sofi, F., Valecchi, D., Bacci, D., Abbate, R., Gensini, G.F., Casini, A., & Macchi, C. (2011). Physical activity and risk of cognitive decline: a meta-analysis of prospective studies. *Journal of Internal Medicine, 269*, 107-117. doi: 10.1111/j.1365-2796.2010.02281.x

Sorel, O., & Pennequin, V. (2008). Aging of the planning process: the role of executive functioning. *Brain and Cognition, 66*, 196-201. doi: 10.1016/j.bandc.2007.07.006

Stevens, J.P. (2002). *Applied multivariate statistics for the social sciences (4th Ed.)*. Mahwah: Lawrence Erlbaum Associates.

Stone, A.A., & Shiffman, S. (2002). Capturing momentary, self-report data: a proposal for reporting guidelines. *Annals of behavioral medicine, 24*, 236-243. doi: 10.1207/S15324796ABM2403_09

Strack, F., & Deutsch, R. (2004). Reflective and impulsive determinants of social behavior. *Personality and Social Psychology Review, 8*, 220-247. doi: 10.1207/s15327957pspr0803_1

Štulhofer, A., Baćak, V., Ajduković, D., & Graham, C. (2010). Understanding the association between condom use at first and most recent sexual intercourse: an assessment of normative, calculative, and habitual explanations. *Social Science & Medicine, 70*, 2080-2084. doi: 10.1016/j.socscimed.2010.02.030

Sun, F., Norman, I.J., & While, A.E. (2013). Physical activity in older people: a systematic review. *BMC Public Health, 13:449*. doi: 10.1186/1471-2458-13-449

Sutton, S. (1994). The past predicts the future: interpreting behaviour-behaviour relationships in social psychological models of health behaviour. In D.R. Rutter & L. Quine (Eds.), *Social psychology and health: European perspectives* (pp. 71-88). Brookfield: Avebury/Ashgate Publishing.

Sutton, S. (1998). Predicting and explaining intentions and behavior: how well are we doing? *Journal of Applied Social Psychology, 28*, 1317-1338. doi: 10.1111/j.1559-1816.1998.tb01679.x

T

Tabachnick, B.G., & Fidell, L.S. (2007). *Using multivariate statistics (5th Ed.)*. Boston: Allyn and Bacon.

Taylor, A.H., Cable, N.T., Faulkner, G., Hillsdon, M., Narici, M., & Van der Bij, A.K. (2004). Physical activity and older adults: a review of health benefits and the effectiveness of interventions. *Journal of Sports Sciences, 22*, 703-725. doi: 10.1080/02640410410001712421

Thibaud, M., Bloch, F., Tournoux-Facon, C., Brèque, C., Rigaud, A.S., Dugué, B., & Kemoun, G. (2012). Impact of physical activity and sedentary behaviour on fall risks in older people: a systematic review and meta-analysis of observational studies. *European Review of Aging and Physical Activity, 9*, 5-15. doi: 10.1007/s11556-011-0081-1

Thorndike, E.L. (1911). *Animal intelligence. Experimental studies*. New York: The MacMillan Company.

Tofighi, D., & MacKinnon, D.P. (2011). RMediation: an R package for mediation analysis confidence intervals. *Behavior Research Methods, 43*, 692-700. doi: 10.3758/s13428-011-0076-x

Tolman, E.C. (1948). Cognitive maps in rats and men. *Psychological Review, 55*, 189-208. doi: 10.1037/h0061626

TNO (2007). *Trendrapport. Bewegen en gezondheid 2004/2005 [Trend report. Physical activity and health 2004/2005]*. Leiden: TNO.

TNO (2015). *Trendrapport. Bewegen en Gezondheid 2000/2014 [Trend report. Phsyical activity and health 2000/2014]*. Leiden: TNO.

Trafimow, D. (2000). Habit as both a direct cause of intention to use a condom and as a moderator of the attitude-intention and subjective norm-intention relations. *Psychology & Health, 15*, 383-393. doi: 10.1080/08870440008402000

Triandis, H.C. (1977). *Interpersonal behavior*. Monterey: Brooks/Cole.

Triandis, H.C. (1980). Values, attitudes, and interpersonal behavior. In M.M. Page (Ed.), *Nebraska symposium on motivation 1979. Beliefs, attitudes, and values* (pp. 195-259). Lincoln: University of Nebraska Press.

Troiano, R.P. (2009). Can there be a single best measure of reported physical activity? *American Journal of Clinical Nutrition, 89*, 736-737. doi: 10.3945/ajcn.2008.27461

U

United Nations (2015). *World population ageing 2015*. New York: United Nations.

V

Van Bree, R.J.H., Van Stralen, M.M., Bolman, C., Mudde, A.N., De Vries, H., & Lechner, L. (2013). Habit as moderator of the intention-physical activity relationship in older adults: a longitudinal study. *Psychology & Health, 28*, 514-532. doi: 10.1080/08870446.2012.749476

Van Bree, R.J.H., Van Stralen, M.M., Mudde, A.N., Bolman, C., De Vries, H., & Lechner, L. (2015). Habit as mediator of the relationship between prior and later physical activity: a longitudinal study in older adults. *Psychology of Sport and Exercise, 19*, 95-102. doi: 10.1016/j.psychsport.2015.03.006

Van de Schoot, R., Lugtig, P., & Hox, J. (2012). A checklist for testing measurement invariance. *European Journal of Developmental Psychology, 9*, 486-492. doi: 10.1080/17405629.2012.686740

Van der Bij, A.K., Laurant, M.G.H., & Wensing, M. (2002). Effectiveness of physical activity interventions for older adults. A review. *American Journal of Preventive Medicine, 22*, 120-133. doi: 10.1016/S0749-3797(01)00413-5

Van Stralen, M.M. (2010). *The Active Plus Project. Changing physical activity behaviour in older adults*. Unpublished doctoral dissertation, Open Universiteit Nederland, Heerlen.

Van Stralen, M.M., De Vries, H., Mudde, A.N., Bolman, C., & Lechner, L. (2009a). Determinants of initiation and maintenance of physical activity among older adults: a literature review. *Health Psychology Review, 3*, 147-207. doi: 10.1080/17437190903229462

Van Stralen, M.M., De Vries, H., Mudde, A.N., Bolman, C., & Lechner, L. (2009b). Efficacy of two tailored interventions promoting physical activity in older adults. *American Journal of Preventive Medicine, 37*, 405-417. doi: 10.1016/j.amepre.2009.07.009

Van Stralen, M.M., De Vries, H., Mudde, A.N., Bolman, C., & Lechner, L. (2011). The long-term efficacy of two computer-tailored physical activity interventions for older adults: main effects and mediators. *Health Psychology, 30*, 442-452. doi: 10.1037/a0023579

Van Stralen, M.M., Kok, G., De Vries, H., Mudde, A.N., Bolman, C., & Lechner, L. (2008). The Active *plus* protocol: systematic development of two theory- and evidence-based tailored physical activity interventions for the over-fifties. *BMC Public Health, 8:399*. doi: 10.1186/1471-2458-8-399

Van Stralen, M.M., Lechner, L., Mudde, A.N., De Vries, H., & Bolman, C. (2010). Determinants of awareness, initiation and maintenance of physical activity among the over-fifties: a Delphi study. *Health Education Research, 25*, 233-247. doi: 10.1093/her/cyn045

Vanhees, L., Lefevre, J., Philippaerts, R., Martens, M., Huygens, W., Troosters, T., & Beunen, G. (2005). How to assess physical activity? How to assess physical fitness? *European Journal of Cardiovascular Prevention and Rehabilitation, 12*, 102-114. doi: 10.1097/01.hjr.0000161551.73095.9c

Vermeulen, J., Neyens, J.C.L., Van Rossum, E., Spreeuwenberg, M.D., & De Witte, L.P. (2011). Predicting ADL disability in community-dwelling elderly people using physical frailty indicators: a systematic review. *BMC Geriatrics, 11:33*. doi: 10.1186/1471-2318-11-33

Verplanken, B. (2005). Habits and implementation intentions. In J. Kerr, R. Weitkunat & M. Moretti (Eds.), *The ABC of behavioural change* (pp. 99-109). Oxford: Elsevier Science.

Verplanken, B. (2006). Beyond frequency: habit as mental construct. *British Journal of Social Psychology, 45*, 639-656. doi: 10.1348/014466605X49122

Verplanken, B. (2010). By force of habit. In A. Steptoe (Ed.), *Handbook of behavioral medicine: methods and applications* (pp. 73-82). New York: Springer.

Verplanken, B., Aarts, H., & Van Knippenberg, A. (1997). Habit, information acquisition, and the process of making travel mode choices. *European Journal of Social Psychology, 27*, 539-560. doi: 10.1002/(SICI)1099-0992(199709/10)27:5<539::AID-EJSP831>3.0.CO;2-A

Verplanken, B., Aarts, H., Van Knippenberg, A., & Moonen, A. (1998). Habit versus planned behaviour: a field experiment. *British Journal of Social Psychology, 37*, 111-138. doi: 10.1111/j.2044-8309.1998.tb01160.x

Verplanken, B., Aarts, H., Van Knippenberg, A., & Van Knippenberg, C. (1994). Attitude versus general habit: antecedents of travel mode choice. *Journal of Applied Social Psychology, 24*, 285-300. doi: 10.1111/j.1559-1816.1994.tb00583.x

Verplanken, B., & Melkevik, O. (2008). Predicting habit: the case of physical exercise. *Psychology of Sport and Exercise, 9*, 15-26. doi: 10.1016/j.psychsport.2007.01.002

Verplanken, B., Myrbakk, V., & Rudi, E. (2005). The measurement of habit. In T. Betsch & S. Haberstroh (Eds.), *The routines of decision making* (pp. 231-247). Mahwah: Lawrence Erlbaum Associates.

Verplanken, B., & Orbell, S. (2003). Reflections on past behavior: a self-report index of habit strength. *Journal of Applied Social Psychology, 33*, 1313-1330. doi: 10.1111/j.1559-1816.2003.tb01951.x

Verplanken, B., & Roy, D. (2015). Consumer habits and sustainable consumption. In L.A. Reisch & J. Thøgersen (Eds.), *Handbook of research on sustainable consumption* (pp. 243-253). Cheltenham: Edward Elgar Publishing.

Verplanken, B., & Wood, W. (2006). Interventions to break and create consumer habits. *Journal of Public Policy & Marketing, 25*, 90-103. doi: 10.1509/jppm.25.1.90

Visser, M., Pluijm, S.M.F., Stel, V.S., Bosscher, R.J., & Deeg, D.J.H. (2002). Physical activity as a determinant of change in mobility performance: the Longitudinal Aging Study Amsterdam. *Journal of the American Geriatrics Society, 50*, 1774-1781. doi: 10.1046/j.1532-5415.2002.50504.x

Vogel, T., Brechat, P-H., Leprêtre, P-M., Kaltenbach, G., Berthel, M., & Lonsdorfer, J. (2009). Health benefits of physical activity in older patients: a review. *International Journal of Clinical Practice, 63*, 303-320. doi: 10.1111/j.1742-1241.2008.01957.x

W

Wagenmakers, R., Van den Akker-Scheek, I., Groothoff, J.W., Zijlstra, W., Bulstra, S.K., Kootstra, J.W.J., Wendel-Vos, G.C.W., Van Raaij, J.J.A.M., & Stevens, M. (2008). Reliability and validity of the short questionnaire to assess health-enhancing physical activity (SQUASH) in patients after total hip arthroplasty. *BMC Musculoskeletal Disorders*, *9:141*. doi: 10.1186/1471-2474-9-141

Wang, J., & Wang, X. (2012). *Structural equation modeling: applications using Mplus*. New York: Wiley.

Wang, X. (2011). The role of anticipated negative emotions and past behavior in individuals' physical activity intentions and behaviors. *Psychology of Sport and Exercise, 12*, 300-305. doi: 10.1016/j.psychsport.2010.09.007

Wanner, M., Probst-Hensch, N., Kriemler, S., Meier, F., Bauman, A., & Martin, B.W. (2014). What physical activity surveillance needs: validity of a single-item questionnaire. *British Journal of Sports Medicine, 48*, 1570-1576. doi: 10.1136/bjsports-2012-092122

Warburton, D.E.R., Nicol, C.W., & Bredin, S.S.D. (2006). Health benefits of physical activity: the evidence. *Canadian Medical Association Journal, 174*, 801-809. doi: 10.1503/cmaj.051351

Warner, L.M., Wolff, J.K., Ziegelmann, J.P., Schwarzer, R., & Wurm, S. (2016). Revisiting self-regulatory techniques to promote physical activity in older adults: null-findings from a randomised controlled trial. *Psychology & Health, 31*, 1145-1165. doi: 10.1080/08870446.2016.1185523

Wason, P.C., & Evans, J.St.B.T. (1974). Dual processes in reasoning? *Cognition, 3*, 141-154. doi: 10.1016/0010-0277(74)90017-1

Watkins, E.R., & Nolen-Hoeksema, S. (2014). A habit-goal framework of depressive rumination. *Journal of Abnormal Psychology, 123*, 24-34. doi: 10.1037/a0035540

Watson, J.B. (1913). Psychology as the behaviorist views it. *Psychological Review, 20*, 158-177. doi: 10.1037/h0074428

Webb, T.L., & Sheeran, P. (2006). Does changing behavioral intentions engender behavior change? A meta-analysis of the experimental evidence. *Psychological Bulletin, 132*, 249-268. doi: 10.1037/0033-2909.132.2.249

Weiss, T.W., Slater, C.H., Green, L.W., Kennedy, V.C., Albright, D.L., & Wun, C-C. (1990). The validity of single-item, self-assessment questions as measures of adult physical activity. *Journal of Clinical Epidemiology, 43*, 1123-1129. doi: 10.1016/0895-4356(90)90013-F

Wells, Y. (2016). Life events and older people. In N.A. Pachana (Ed.), *Encyclopedia of Gerontology* (pp. 1-9). Singapore: Springer.

Wendel-Vos, W., & Schuit, J. (2004). *Squash. Short questionnaire to assess health enhancing physical activity*. Bilthoven: Centrum voor Preventie en Zorgonderzoek, Rijksinstituut voor Volksgezondheid en Milieu.

Wiers, R.W., Bartholow, B.D., Van den Wildenberg, E., Thush, C., Engels, R.C.M.E., Sher, K.J., Grenard, J., Ames, S.L., & Stacy, A.W. (2007). Automatic and controlled processes and the development of addictive behaviors in adolescents: a review and a model. *Pharmacology, Biochemistry and Behavior, 86*, 263-283. doi: 10.1016/j.pbb.2006.09.021

Wolff, J.K., Warner, L.M., Ziegelmann, J.P., & Wurm, S. (2014). What do targeting positive views on ageing add to a physical activity intervention in older adults? Results from a randomised controlled trial. *Psychology & Health, 29*, 915-932. doi: 10.1080/08870446.2014.896464

Wolff, J.K., Warner, L.M., Ziegelmann, J.P., Wurm, S., & Kliegel, M. (2016). Translating good intentions into physical activity: older adults with low prospective memory ability profit from planning. *Journal of Behavioral Medicine, 39*, 472-482. doi: 10.1007/s10865-015-9707-5

Wong, C.L., & Mullan, B.A. (2009). Predicting breakfast consumption: an application of the theory of planned behaviour and the investigation of past behaviour and executive function. *British Journal of Health Psychology, 14*, 489-504. doi: 10.1348/135910708X360719

Wood, W., & Neal, D.T. (2007). A new look at habits and the habit-goal interface. *Psychological Review, 114*, 843-863. doi: 10.1037/0033-295X.114.4.843

Wood, W., & Neal, D.T. (2009). The habitual consumer. *Journal of Consumer Psychology, 19*, 579-592. doi: 10.1016/j.jcps.2009.08.003

Wood, W., & Rünger, D. (2016). Psychology of habit. *Annual Review of Psychology, 67*, 289-314. doi: 10.1146/annurev-psych-122414-033417

Wood, W., Quinn, J.M., & Kashy, D.A. (2002). Habits in everyday life: thought, emotion, and action. *Journal of Personality and Social Psychology, 83*, 1281-1297. doi: 10.1037//0022-3514.83.6.1281

Wood, W., Tam, L., & Guerrero Witt, M. (2005). Changing circumstances, disrupting habits. *Journal of Personality and Social Psychology, 88*, 918-933. doi: 10.1037/0022-3514.88.6.918

World Health Organization (2011). Physical inactivity. Retrieved October 13, 2011, from http://apps.who.int/ghodata/

Wouters, S., Thewissen, V., Duif, M., Van Bree, R.J.H., Lechner, L., & Jacobs, N. (in press). Habit strength and between-meal snacking in daily life: the moderating role of level of education. *Public Health Nutrition*.

Wu, M-C., & Kuo, F-Y. (2008). An empirical investigation of habitual usage and past usage on technology acceptance evaluations and continuance intention. *ACM SIGMIS Database: the DATABASE for Advances in Information Systems, 39*, 48-73. doi: 10.1145/1453794.1453801

Z

Ziegelmann, J.P., Lippke, S., & Schwarzer, R. (2006). Adoption and maintenance of physical activity: planning interventions in young, middle-aged, and older adults. *Psychology & Health, 21*, 145-163. doi: 10.1080/14768320500188991

CHAPTER 8

ADDENDA

SUMMARY

It is well-established that for older adults a physically active lifestyle is highly beneficial for health. Public health guidelines state that all adults should be at least moderately physically active for at least 30 minutes per day on at least five days per week. Unfortunately, a large proportion of older adults do not meet this physical activity (PA) recommendation. These older adults are insufficiently physically active to obtain the health benefits associated with regular and sufficient PA. Promoting PA in older adults is therefore of major relevance. Development of effective interventions to promote PA relies on insight into the determinants of PA and their working mechanisms. A determinant that merits examination in this regard is habit. The potential importance of habit lies in its close ties to PA maintenance, which, in turn, is essential for obtaining many health benefits. Although research has already revealed that PA has a habitual component, the longitudinal relationship between habit and PA can still be unraveled in more depth. The aim of this thesis is to contribute to a more comprehensive understanding of habit's relation to PA. This understanding may inform intervention development.

Chapter 1 describes the concept of habit, provides a brief history of habit from a psychological perspective, and defines PA for all studies in this thesis as the number of days per week on which a participant was at least moderately physically active for at least 30 minutes. Furthermore, this chapter describes that in health psychology for years the dominant approach has been to consider health behavior the result of a conscious, explicit, rational decision making process. This approach is known as the social cognitive approach. However, a more complete account of behavior can be achieved when in addition to explicit cognitions, such as intentions and attitudes, implicit processes, such as habits, are recognized. Models that account for both explicit, conscious influences and implicit, unconscious processes on behavior are called dual-process models. The first two studies of this thesis are concerned with PA as the outcome of a dual-process. The third and fourth study of this thesis test several mediation effects in which habit and PA play several roles. Chapter 1 specifies the research questions of the studies in this thesis in detail. All studies are conducted in older adults, aged 50 years or older.

Chapter 2 presents a study that examined whether habit strength moderates the intention-physical activity (PA) relationship within the framework of the theory of planned behavior (TPB) and the attitude-social influences-efficacy (ASE) model. A longitudinal design with two measurement points was applied. Three PA habit groups were composed: a low, a medium, and a high PA habit group. The results of structural equation modeling (SEM) analyses showed that intention only significantly determined PA in the low and medium PA habit groups, implying that PA was not intentional at

high levels of habit strength. Habit operated as a moderator of the intention-PA relationship. It is therefore recommended to add habit to the TPB/ASE model. This would transform this social cognitive model into a model that has characteristics of a dual-process model. As strong habits may limit the potential to change PA intentionally, only applying persuasive messaging as an intervention strategy may not suffice, and additional intervention strategies are needed for strongly habitual, but insufficiently active older adults.

Chapter 3 shows a study that targeted the question why prior PA is a good predictor of later PA, even after TPB/ASE variables have been taken into account. This question is known as the residual variance problem. It has been suggested that habit operates as a mediator between prior and later behavior and as such forms at least a partial solution to the residual variance problem. In other words, prior behavior is proposed to exert its influence on later behavior through habit. This proposition was tested using a longitudinal design with four measurement points. Path analyses showed that habit indeed significantly mediated the relationship between prior and later PA, after TPB/ASE variables were taken into account. This result indicates that habit is a partial solution to the question why prior PA is a good predictor of later PA. It is recommended to incorporate habit into the TPB/ASE model.

Chapter 2 and 3 both present studies that recommend to add habit to the TPB/ASE model. In these two chapters habit appears in two different roles: as a moderator that is concurrently assessed with intention, and as a post-intentional predictor of PA. Both roles not only indicate that habits have to be taken into account when explaining and predicting PA and when designing PA interventions based on the TPB/ASE model, but also that habit is a relevant construct in different phases that precede PA. The studies indicate that there is reason to consider incorporating habit into the TPB/ASE model in both roles. Both studies modeled habit as a variable that precedes PA. Additional insight into habit's relation to PA can be achieved by modeling PA as a variable that precedes habit. In both Chapter 4 and 5 PA appears as a variable that affects habit.

Chapter 4 reports on a study that applied a cross-lagged panel design to examine whether habit mediates the relationship between prior and later PA and whether PA simultaneously mediates the relationship between prior and later habit. The hypothesis that both mediation effects occur simultaneously was tested in two independent samples of older adults. While a significant PA-habit-PA path would support the implicit assumption underlying many PA interventions that PA sustains over time through habit, a significant habit-PA-habit path would indicate that PA interventions could benefit from incorporating habit formation strategies. The results of SEM analyses were not

unambiguous. Indications for the existence of both hypothesized mediation effects were found, but no clear, unequivocal pattern appeared. Somewhat more support was found for the PA-habit-PA path than for the habit-PA-habit path. More research is needed to draw more definitive conclusions.

Chapter 5 presents a study that modeled habit as an outcome variable. Habit formation has been proposed as a way to ensure long-term maintenance of PA and, as such, as a desired outcome of PA interventions. Intention, action planning (AP), and PA are suggested to be determinants of PA habits. It is, however, largely unknown how they determine PA habits. In two independent samples of older adults, the hypothesis was tested that the relationship between intention and habit is mediated by AP and/or PA. A four-wave longitudinal design was used. SEM analyses showed significant intention-PA-habit paths and nonsignificant intention-AP-habit and intention-AP-PA-habit paths in both samples. Thus, the relationship between intention and PA habit was mediated by PA and intention was neither associated with habit via AP as a single mediator, nor via AP and PA as sequential mediators. Possible conditions under which intention-AP-habit paths and intention-AP-PA-habit paths exist are discussed in detail.

Chapter 6 provides a summary and discussion of the main findings of the studies in this thesis, discusses methodological issues, and indicates implications for practice and directions for future research. A major strength of the studies in this thesis is the study population of older adults. Older adults are an underrepresented population in habit research. In light of both the rapid growth of this population and the large proportion of insufficiently physically active older adults, it is relevant to target older adults in PA habit research. Other major strengths are the large number of participants, the longitudinal design with four measurement points, and the use of two datasets in two studies. Limitations include the considerable and selective dropout and the measurement of PA by self-reports. The strengths and limitations should be taken into account when interpreting the findings of this thesis. Important implications for practice are that existing habits have to be taken into account when developing PA promotion interventions for older adults based on the TPB/ASE model, and that it may be worthwhile to incorporate habit formation strategies, such as the use of reminders and self-monitoring, into interventions to improve the translation of PA into PA habits. An important direction for future research consists of close replications of the studies in this thesis as well as replications with variations in study population, time intervals, and target behavior. Other directions for future research include conducting experimental tests of the efficacy of habit formation strategies, gaining insight into the process of habit formation for different age groups, and testing the stability and development of habit over time.

To conclude, this thesis shows that habit and PA are longitudinally connected with each other in several ways; there is continuous, reciprocal influence between habit and PA. Habits have to be taken into account when explaining, predicting, influencing, and maintaining PA. Being sufficiently physically active is associated with many health benefits. Through their influence on PA, habits for sufficient PA contribute to obtaining these health benefits.

SAMENVATTING

Het is welbekend dat een leefstijl met voldoende lichaamsbeweging voor oudere volwassenen grote gezondheidsvoordelen heeft. De beweegnorm schrijft voor dat alle volwassenen op minimaal vijf dagen per week minimaal 30 minuten lang op minimaal matig intensief niveau moeten bewegen. Helaas voldoet een groot deel van de oudere volwassenen niet aan deze richtlijn. Deze groep van oudere volwassenen beweegt niet genoeg om de gezondheidsvoordelen van regelmatig voldoende beweging te behalen. Het bevorderen van beweeggedrag is daarom van groot belang. Voor het ontwikkelen van effectieve interventies die beweeggedrag stimuleren is het noodzakelijk een goed inzicht te hebben in de determinanten van beweeggedrag en hun werkingsmechanismen. Een determinant die in dat opzicht meer onderzoek behoeft is gewoonte. Het mogelijke belang van gewoonte schuilt in de nauwe band tussen gewoonte en het volhouden van beweeggedrag. Dat laatste is essentieel voor het behalen van veel gezondheidsvoordelen. Ondanks dat onderzoek reeds heeft aangetoond dat beweeggedrag een gewoontecomponent heeft, kan de longitudinale relatie tussen gewoonte en beweeggedrag nog verder uitgediept worden. Het doel van dit proefschrift is bij te dragen aan een beter en meeromvattend begrip van de relatie tussen gewoonte en beweeggedrag, wat uiteindelijk positief bij kan dragen aan het ontwikkelen van interventies.

Hoofdstuk 1 beschrijft het gewoonteconcept, plaatst vanuit een psychologische invalshoek gewoontes in kort historisch perspectief en definieert beweeggedrag voor alle studies in dit proefschrift als het aantal dagen per week waarop een participant minimaal 30 minuten lang op minimaal matig intensief niveau bewogen heeft. Daarnaast beschrijft dit hoofdstuk dat in de gezondheidspsychologie jarenlang de opvatting dominant is geweest dat gezondheidsgedrag de uitkomst is van een bewust, expliciet, beredeneerd beslissingsproces. Deze opvatting staat bekend als de sociaal cognitieve benadering van gezondheidsgedrag. Echter, er ontstaat een completer begrip van gedrag als naast expliciete cognities, zoals intenties en attitudes, ook impliciete processen, zoals gewoontes, in beschouwing worden genomen. Modellen die gedrag verklaren door zowel expliciete, bewuste invloeden, alsook impliciete, onbewuste processen in ogenschouw te nemen, worden duale proces modellen genoemd. De eerste twee studies in dit proefschrift richten zich op beweeggedrag als uitkomst van een dergelijk duaal proces. De derde en vierde studie in dit proefschrift toetsen verschillende mediatie-effecten waarin gewoonte en beweeggedrag verschillende rollen innemen. Hoofdstuk 1 beschrijft de onderzoeksvragen van de studies in dit proefschrift in detail. Alle studies zijn uitgevoerd bij volwassenen van 50 jaar en ouder.

Hoofdstuk 2 presenteert een studie die onderzocht of gewoonte binnen het raamwerk van de theorie van gepland gedrag (TPB) en het attitude-sociale invloeden-eigen effectiviteit (ASE) model de relatie tussen intentie en beweeggedrag modereert. Het longitudinale design kende twee meetmomenten. Er werden drie groepen gevormd op basis van gewoontesterkte: een lage, een midden en een hoge gewoontegroep. De resultaten van structural equation modeling (SEM) analyses lieten zien dat intentie enkel een significante determinant van beweeggedrag was in de lage en midden gewoontegroep. Dat betekent dat beweeggedrag niet intentioneel was als gewoontes sterk waren. Gewoonte modereerde dus de relatie tussen intentie en beweeggedrag. Aanbevolen wordt om gewoonte als variabele toe te voegen aan het TPB/ASE model. Het gevolg hiervan zou zijn dat dit sociaal cognitieve model ook kenmerken van een duaal proces model gaat vertonen. Aangezien sterke gewoontes een beperking vormen voor het intentioneel veranderen van beweeggedrag voldoet de interventiestrategie van het enkel aanbieden van overtuigende boodschappen mogelijk niet en lijken additionele interventiestrategieën nodig voor oudere volwassenen met sterke gewoontes, maar met onvoldoende beweeggedrag.

Hoofdstuk 3 beschrijft een studie die zich richtte op de vraag waarom eerder vertoond beweeggedrag een goede voorspeller is van later beweeggedrag, ook als gecorrigeerd wordt voor de variabelen uit het TPB/ASE model. Deze vraag staat bekend als het residuele variantie probleem. Er is geopperd dat gewoonte een mediator is tussen eerder en later beweeggedrag en dat gewoonte als zodanig tenminste een gedeeltelijke oplossing is voor het residuele variantie probleem. Met andere woorden, er wordt verondersteld dat eerder vertoond beweeggedrag via gewoonte invloed uitoefent op later beweeggedrag. Deze veronderstelling werd getoetst in een longitudinaal design met vier meetmomenten. Voor TPB/ASE variabelen werd gecorrigeerd. Padanalyses lieten inderdaad zien dat gewoonte de relatie tussen eerder en later beweeggedrag significant medieerde. Dit resultaat duidt erop dat gewoonte een gedeeltelijk antwoord is op de vraag waarom eerder vertoond beweeggedrag een goede voorspeller is van later beweeggedrag. Aanbevolen wordt om gewoonte als variabele toe te voegen aan het TPB/ASE model.

Hoofdstuk 2 en 3 laten studies zien waarin aanbevolen wordt om gewoonte als variabele op te nemen in het TPB/ASE model. In deze twee hoofdstukken verschijnt gewoonte in twee verschillende rollen: als een moderator die gelijktijdig met intentie werd gemeten en als een post-intentionele voorspeller van beweeggedrag. Beide rollen laten niet alleen zien dat rekening gehouden moet worden met gewoontes bij het verklaren en voorspellen van beweeggedrag en bij het ontwerpen van interventies die beweeggedrag stimuleren op basis van het TPB/ASE model, maar ook dat gewoonte

een relevante variabele is in verschillende fasen voorafgaand aan beweeggedrag. De studies vormen aanleiding om te overwegen om gewoonte als variabele in beide rollen op te nemen in het TPB/ASE model. Beide studies modelleerden gewoonte als een variabele die voorafgaat aan beweeggedrag. Door beweeggedrag te modelleren als een variabele die voorafgaat aan gewoonte kan extra inzicht worden verkregen in de relatie tussen gewoonte en beweeggedrag. In zowel hoofdstuk 4 als 5 wordt getoetst of beweeggedrag een variabele is die invloed uitoefent op gewoonte.

Hoofdstuk 4 rapporteert een studie die een cross-lagged panel design gebruikte om te onderzoeken of gewoonte de relatie tussen eerder en later beweeggedrag medieert en of beweeggedrag tegelijkertijd de relatie tussen eerdere en latere gewoonte medieert. De hypothese dat beide mediatie-effecten zich gelijktijdig voordoen werd getoetst in twee onafhankelijke steekproeven van oudere volwassenen. Daar waar een significant beweeggedrag-gewoonte-beweeggedrag pad ondersteuning zou bieden aan een impliciete veronderstelling van veel interventies op beweeggedrag, zou een significant gewoonte-beweeggedrag-gewoonte pad erop duiden dat interventies op beweeggedrag kunnen profiteren van het opnemen van strategieën voor gewoontevorming. De resultaten van SEM analyses waren niet eenduidig. Hoewel ze indicaties opleverden voor beide veronderstelde mediatie-effecten, werd er geen duidelijk, ondubbelzinnig patroon gevonden. Er werd iets meer onderbouwing gevonden voor het beweeggedrag-gewoonte-beweeggedrag pad dan voor het gewoonte-beweeggedrag-gewoonte pad. Er is meer onderzoek nodig voordat er meer definitieve conclusies getrokken kunnen worden.

Hoofdstuk 5 presenteert een studie waarin gewoonte fungeerde als uitkomstvariabele. De vorming van gewoontes wordt genoemd als een manier om te waarborgen dat beweeggedrag op de lange termijn bestendigt. Als zodanig is de vorming van gewoontes een gewenste uitkomst van interventies die beweeggedrag stimuleren. Intentie, actie planning en beweeggedrag zijn geopperd als determinanten van gewoontes voor beweeggedrag. Echter, hoe deze variabelen gewoontes voor beweeggedrag beïnvloeden is grotendeels onbekend. In twee onafhankelijke steekproeven onder oudere volwassenen werd getoetst of de relatie tussen intentie en gewoonte wordt gemedieerd door actie planning en/of beweeggedrag. Er werd gebruikgemaakt van een longitudinaal design met vier meetmomenten. SEM analyses toonden in beide steekproeven een significant intentie-beweeggedrag-gewoonte pad en niet-significante intentie-actie planning-gewoonte en intentie-actie planning-beweeggedrag-gewoonte paden. De relatie tussen intentie en gewoonte werd dus gemedieerd door beweeggedrag, maar intentie was niet verbonden met gewoonte via actie planning als enige mediator of met actie planning en beweeggedrag als

opeenvolgende mediatoren. Mogelijke condities waaronder intentie-actie planning-gewoonte paden en intentie-actie planning-beweeggedrag-gewoonte paden bestaan worden in detail besproken.

Hoofdstuk 6 biedt een samenvatting en discussie van de belangrijkste bevindingen van de studies in dit proefschrift, bediscussieert methodologische kwesties en bespreekt praktische implicaties en richtingen voor toekomstig onderzoek. Een belangrijk sterk punt van de studies in dit proefschrift is de studiepopulatie van oudere volwassenen. Oudere volwassenen zijn ondervertegenwoordigd in het gewoonteonderzoek. Met het oog op zowel de snelle groei van deze populatie, alsook het hoge percentage oudere volwassenen dat niet voldoet aan de beweegnorm, is het van groot belang om onderzoek naar gewoontes voor beweeggedrag te verrichten onder oudere volwassenen. Andere belangrijke sterke punten zijn het grote aantal respondenten, het longitudinale design met vier meetmomenten en het gebruik van twee datasets in twee studies. Beperkingen bestaan uit de aanzienlijke en selectieve uitval en uit het meten van beweeggedrag met een zelfrapportagemaat. De sterkte punten en de beperkingen moeten in acht genomen worden bij het interpreteren van de resultaten van dit proefschrift. Belangrijke praktische implicaties zijn dat bestaande gewoontes in ogenschouw genomen moeten worden bij het ontwikkelen van interventies die beweeggedrag bij ouderen volwassenen stimuleren en die gebaseerd zijn op het TPB/ASE model, en dat het zinvol kan zijn om strategieën voor gewoontevorming, zoals het werken met herinneringen en zelfmonitoring, op te nemen in interventies om de vertaalslag van beweeggedrag naar gewoontes voor beweeggedrag te verbeteren. Een belangrijke richting voor toekomstig onderzoek bestaat zowel uit zo precies mogelijke replicaties van de studies in dit proefschrift, alsook uit replicaties met variaties in studiepopulatie, tijdsintervallen en doelgedrag. Andere richtingen voor toekomstig onderzoek zijn het experimenteel toetsen van de effectiviteit van strategieën voor gewoontevorming, het bestuderen van het proces van gewoontevorming voor verschillende leeftijdsgroepen en het in kaart brengen van de stabiliteit en de ontwikkeling van gewoonte over de tijd.

Concluderend laat dit proefschrift zien dat gewoonte en beweeggedrag longitudinaal op verschillende wijzen met elkaar verbonden zijn; er is continue, reciproke invloed tussen gewoonte en beweeggedrag. Gewoontes moeten in ogenschouw genomen worden bij het verklaren, voorspellen, beïnvloeden en bestendigen van beweeggedrag. Voldoende beweeggedrag heeft veel gezondheidsvoordelen. Door hun invloed op beweeggedrag dragen gewoontes voor beweeggedrag bij aan het behalen van deze gezondheidsvoordelen.

ABOUT THE AUTHOR

Rob van Bree was born on November 9, 1977 in Helmond, the Netherlands. After finishing pre-university education in 1998, he attended De Kempel University of Applied Sciences in Helmond, where he was trained to be a primary school teacher. In 2002, Rob obtained his teaching degree. From 2001 to 2007, Rob studied health psychology at the Open University of the Netherlands, from which he graduated cum laude.

Rob worked several years as a part-time teacher at public primary school De Korenbloem in Oirschot. As an active author Rob publishes within the educational domain. Together with his wife Hanneke he has published many well-received articles in professional educational journals, such as *Praxisbulletin* and *Jeugd in school en wereld*. In their articles Rob and Hanneke often bridge the gap between theory and classroom practice. This characteristic is also apparent in Rob and Hanneke's successful book *Met rekenogen gelezen*, which was published in 2011. This book describes the integration of 45 picture books in vivid and sparkling, but goal-oriented mathematics education.

Since 2004 Rob works as a volunteer for MIND Korrelatie. This organization, located in Amersfoort, offers anonymous, professional help with mental and psychosocial problems, by telephone as well as online. From 2009 to 2017 Rob was also a volunteer for 113 Zelfmoordpreventie, a foundation located in Amsterdam. For this organization Rob talked by telephone to people suffering from suicidal ideation, tried to lessen their pain and despair, and sought to mitigate their suicidal thoughts and to prevent them from committing suicide.

In 2010, the Open University of the Netherlands offered Rob the opportunity to write his own PhD proposal. Under the supervision of Lilian Lechner, Catherine Bolman, and Aart Mudde, Rob started his PhD project in 2011. He conducted research on the relationship between habit and physical activity. During his PhD project Rob completed courses in moderation and mediation analysis, longitudinal data analysis, structural equation modeling, and writing and presenting in English. Furthermore, Rob reviewed several articles for journals such as *Psychology & Health*, *Psychology of Sport and Exercise*, *BMJ Open*, and *Psychology, Health & Medicine*. The results of his PhD project were published in several international scientific journals and are described in the current thesis.

SCIENTIFIC CONTRIBUTIONS

International journals

Wouters, S., Thewissen, V., Duif, M., Van Bree, R.J.H., Lechner, L., & Jacobs, N. (in press). Habit strength and between-meal snacking in daily life: the moderating role of level of education. *Public Health Nutrition*.

Van Bree, R.J.H., Bolman, C., Mudde, A.N., Van Stralen, M.M., Peels, D.A., De Vries, H., & Lechner, L. (2017). Modeling longitudinal relationships between habit and physical activity: two cross-lagged panel design studies in older adults. *Journal of Aging and Physical Activity, 25*, 464-473. doi: 10.1123/japa.2016-0212

Van Bree, R.J.H., Mudde, A.N., Bolman, C., Van Stralen, M.M., Peels, D.A., De Vries, H., & Lechner, L. (2016). Are action planning and physical activity mediators of the intention-habit relationship? *Psychology of Sport and Exercise, 27*, 243-251. doi: 10.1016/j.psychsport.2016.09.004

Van Bree, R.J.H., Van Stralen, M.M., Mudde, A.N., Bolman, C., De Vries, H., & Lechner, L. (2015). Habit as mediator of the relationship between prior and later physical activity: a longitudinal study in older adults. *Psychology of Sport and Exercise, 19*, 95-102. doi: 10.1016/j.psychsport.2015.03.006

Van Bree, R.J.H., Van Stralen, M.M., Bolman, C., Mudde, A.N., De Vries, H., & Lechner, L. (2013). Habit as moderator of the intention-physical activity relationship in older adults: a longitudinal study. *Psychology & Health, 28*, 514-532. doi: 10.1080/08870446.2012.749476

Congress contributions

Jacobs, N., Wouters, S., Duif, M., Van Bree, R., Lechner, L., & Thewissen, V. (2016, July). *To snack or not to snack: the force of habit in daily life snacking*. Oral session presented at the 31st International Congress of Psychology (ICP), Yokohama, Japan.

Van Bree, R.J.H., Bolman, C., Van Stralen, M.M., Mudde, A.N., De Vries, H., & Lechner, L. (2013, May). *Modelling mediated relationships between habit and physical activity: a cross-lagged panel design study in older adults*. Poster session presented at the 12th annual meeting of the International Society of Behavioral Nutrition and Physical Activity (ISBNPA), Ghent, Belgium.

Van Bree, R.J.H., Van Stralen, M.M., Mudde, A.N., Bolman, C., De Vries, H., & Lechner, L. (2013, May). *Habit as mediator of the relationship between prior and later physical activity: a longitudinal study in older adults*. Poster session presented at the 12th annual meeting of the International Society of Behavioral Nutrition and Physical Activity (ISBNPA), Ghent, Belgium.

PROFESSIONAL CONTRIBUTIONS

Book

Van Bree, R., & Van Bree, H. (2011). *Met rekenogen gelezen. Rekenactiviteiten voor jonge kinderen bij 45 prentenboeken*. Leuven: Acco.

National journals

Van Bree, R., Van Bree, H., Van Sleeuwen, D., & Wigard, E. (2017). Werken met een doelenkaart. Doelbewust rekenen in groep 3. *Jeugd in school en wereld, 102(3)*, 18-21.

Van Bree, R., & Van Bree, H. (2017). Rekenen met de Gruffalo. Kinderboekenweek 2017. *De wereld van het jonge kind, 45(1)*, 4-7.

Van Bree, R. (2017). Zelfmoordgedachten bij leerlingen? Vraag ernaar! *Didactief*. Published May 17, 2017, on http://bit.ly/2pP1V0e

Van Bree, R., De Geus, B., & Van Bree, H. (2017). Een workshop impressionistische fotografie. *Praxisbulletin, 34(5)*, 5-9.

Van Bree, H., & Van Bree, R. (2016). Woordrijen lezen: van saai naar speels. *Praxisbulletin, 34(3)*, 26-29.

Van Bree, R., & Van Bree, H. (2014). Rekenfeesten. Rekenen in de Kinderboekenweek. *De wereld van het jonge kind, 42(1)*, 4-7.

Van Bree, R., & Van Bree, H. (2014). Rekenvoetbal. Rekenactiviteiten bij een voetbalprentenboek. *Praxisbulletin, 31(9)*, 5-8.

Van Bree, R., & Van Bree, H. (2014). Rekenpotentieel van prentenboeken. Een stappenplan voor beoordeling. *Jeugd in school en wereld, 98(8)*, 18-21.

Van Bree, R., Van Bree, H., & Meeusen, K. (2014). Workshop reclamefotografie. Balanceren tussen opvallen en informeren. *Praxisbulletin, 31(8)*, 16-21.

Van Bree, R., & Van Bree, H. (2014). Rekenen op de boerderij. Meetkunde- en telactiviteiten bij drie boerderijprentenboeken. *Volgens Bartjens, 33(4)*, 22-25.

Van Bree, R., Van Bree, H., & De Geus, B. (2013). Een workshop macrofotografie. Kleine voorwerpen groot in beeld. *Praxisbulletin, 30(10)*, 10-14.

Van Bree, R., & Van Bree, H. (2013). Rekenfeesten in prentenboeken. *Praxisbulletin, 30(6)*, 81-85.

Van Bree, R., Van Bree, H., & Meeusen, K. (2013). Een workshop portretfotografie. Van kiekje naar kunst. *Praxisbulletin, 30(5)*, 10-14.

Van Bree, R., & Van Bree, H. (2012). Het aanleren van de klank-letterkoppeling. De voorschotbenadering: praktische handvatten voor fase 3. *Taal lezen primair, No. 2*, 20-23.

Van Bree, R., & Van Bree, H. (2012). Het manipuleren van klanken en letters. De voorschotbenadering: praktische handvatten voor fase 2. *Taal lezen primair, No. 2*, 6-8.

Van Bree, R., & Van Bree, H. (2012). Hallo wereld! Hallo rekenen! Rekenactiviteiten voor groep 1 en 2 bij drie prentenboeken. *Volgens Bartjens, 32(2)*, 22-24.

Van Bree, R., & Van Bree, H. (2012). Het letterfeest. Werken aan letterkennis. *De wereld van het jonge kind, 40(3)*, 10-13.

Van Bree, R., & Van Bree, H. (2012). Het identificeren van klanken en letters. De voorschotbenadering: praktische handvatten voor fase 1. *Taal lezen primair, No. 1*, 11-13.

Van Bree, R., & Van Bree, H. (2012). Verborgen rekenschatten. Rekenactiviteiten ontdekken in prentenboeken. *De wereld van het jonge kind, 39(6)*, 28-31.

Van Bree, R., Meeusen, K., & Van Bree, H. (2012). Een workshop kunstfotografie. In de voetsporen van Edward Burtynsky. *Praxisbulletin, 29(5)*, 26-30.

Van Bree, R., & Van Bree, H. (2011). Heldenverhalen schrijven. *Jeugd in school en wereld, 96(1)*, 12-15.

Van Bree, R., & Van Bree, H. (2008). Werken met een verteltafel. *De wereld van het jonge kind, 36(1)*, 14-16.

Van Bree, R., & Van Bree, H. (2008). Werken met een lettertafel. *De wereld van het jonge kind, 35(7)*, 213-215.

Van Bree, R., & Van Bree, H. (2008). Boeken vol geheimen, rekenen met prentenboeken. Meet- en meetkundeactiviteiten voor groep 1 en 2. *Volgens Bartjens…, 27(3)*, 8-10.

Van Bree, R., & Van Bree, H. (2007). Werken aan tussendoelen met prentenboeken. *De wereld van het jonge kind, 35(1)*, 27-30.

Van Bree, R., & Derks, H. (2002). Het liedjesplein. Op speelse wijze omgaan met tellen, cijfers en getallen in groep 1 en 2. *Willem Bartjens, 21(5)*, 34-37.

Columns

Van Bree, R. (2004). Te gast. *Jeugd in school en wereld, 88(9)*, 17.

Van Bree, R. (2004). Omgekeerde wereld. *Jeugd in school en wereld, 88(7)*, 13.

Van Bree, R. (2004). All children are equal? *Jeugd in school en wereld, 88(6)*, 17.

Van Bree, R. (2004). Duidelijkheid. *Jeugd in school en wereld, 88(5)*, 24.

Van Bree, R. (2003). Spagaat. *Jeugd in school en wereld, 88(3)*, 29.

Van Bree, R. (2003). Regels van klasse. *Jeugd in school en wereld, 88(2)*, 37.

Van Bree, R. (2003). Groeistoornis. *Jeugd in school en wereld, 88(1)*, 24.

Van Bree, R. (2003). Afkoelen. *Jeugd in school en wereld, 87(10)*, 3.

Van Bree, R. (2003). Drawing hands. *Jeugd in school en wereld, 87(9)*, 3.

Van Bree, R. (2003). Hoogbegaafd? *Jeugd in school en wereld, 87(8)*, 3.

Van Bree, R. (2003). Kennistekort. *Jeugd in school en wereld, 87(6)*, 3.

Van Bree, R. (2002). Detailtekenaar. *Jeugd in school en wereld, 87(1)*, 3.

Van Bree, R. (2002). Twee in een. *Jeugd in school en wereld, 86(9)*, 3.

Van Bree, R. (2002). I think. *Jeugd in school en wereld, 86(7)*, 15.

Van Bree, R. (2002). Timmerman worden. *Jeugd in school en wereld, 86(5)*, 3.

Van Bree, R. (2001). Eerlijkheid. *Jeugd in school en wereld, 86(1)*, 3.

Van Bree, R. (1999). Bedremmeld op de drempel. *Jeugd in school en wereld, 84(4)*, 3.

Invited talks

Van Bree, R., & Van Bree, H. (2018, June). *Met rekenogen lezen. Theorie en praktijk*. Presentation for Bibliotheek Helmond-Peel, Helmond, The Netherlands.

Van Bree, R., & Van Bree, H. (2018, May). *Met rekenogen lezen. Een blik op de praktijk*. Presentation for Bibliotheek Helmond-Peel, Helmond, The Netherlands.

Van Bree, R. (2018, February). *Zelfmoordpreventie bij MIND Korrelatie*. Presentation for MIND Korrelatie, Amersfoort, The Netherlands.

Van Bree, R., & Keukelaar, K. (2017, September). *Zelfmoordpreventie aan De Kindertelefoon*. Presentation for De Kindertelefoon, Tilburg, The Netherlands.

Van Bree, R., & Van Bree, H. (2017, June). *Met rekenogen leren lezen*. Presentation for Onderwijsgroep Zuid-Hollandse Waarden, Ridderkerk, The Netherlands.

DANKWOORD

Graag wil ik een aantal mensen bedanken die mij tijdens mijn promotietraject terzijde hebben gestaan.

Allereerst bedank ik Lilian, Catherine en Aart. Jullie zijn bijzonder betrokken begeleiders. Ik ben jullie veel dank verschuldigd voor de soepele samenwerking, de inspirerende overleggen en voor het vleugje humor dat bij jullie altijd dicht onder de oppervlakte ligt. Ook bedank ik jullie voor jullie begrip voor mijn vaak grillige werktempo.

Maartje, jij hebt zeker in de beginfase mijn promotietraject impulsen gegeven, niet alleen door jouw onderzoeksdata beschikbaar te stellen, maar ook door je niet aflatende enthousiasme en enorme betrokkenheid. Heel erg bedankt. Het doet me goed dat jij en Anneke tijdens de promotie als paranimfen naast me staan.

Denise, bedankt dat ik mocht putten uit jouw onderzoeksdata. Hein, bedankt voor de inbreng van jouw wijsheid en jouw brede blik op het vakgebied van de gezondheidspsychologie.

Graag bedank ik de leden van de leescommissie en de overige leden van de corona voor het lezen en beoordelen van dit proefschrift.

Met veel liefde dank ik mijn ouders, die me altijd gestimuleerd hebben te studeren en me te ontwikkelen. Helaas maakt mijn vader mijn promotie niet mee. Mam, ik hoop dat jij trots bent voor twee.

Hanneke, tot slot bedank ik jou kort en krachtig, omdat je niet van lange dankwoorden houdt. *You were there, every step of the way* (De Burgh, 2011). Bedankt!

Rob

Open Universiteit
www.ou.nl